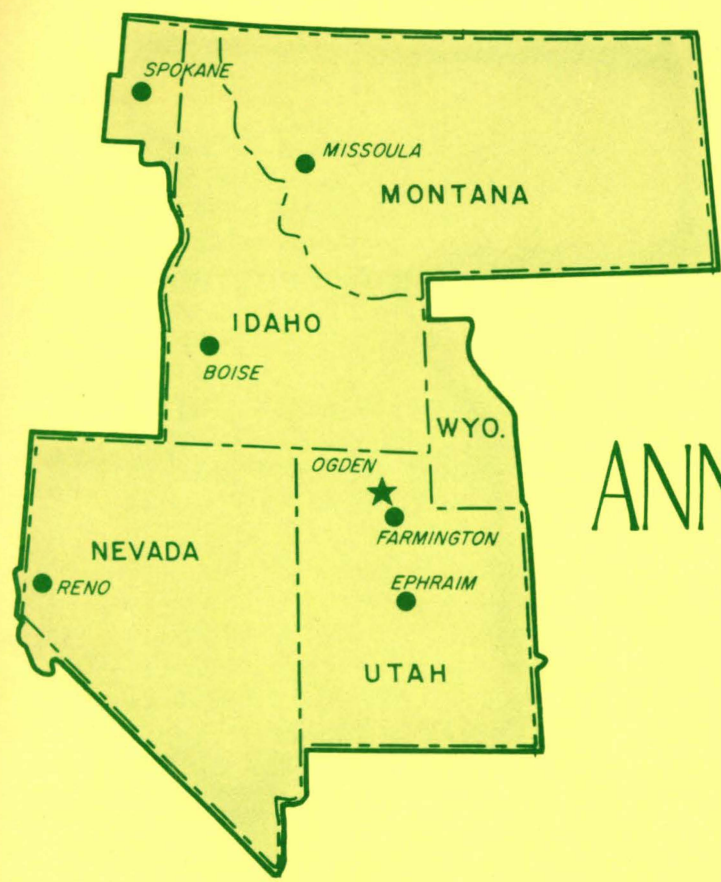


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ANNUAL REPORT

1957

INTERMOUNTAIN FOREST & RANGE EXPERIMENT STATION

FOREST SERVICE
U. S. DEPARTMENT OF AGRICULTURE

OGDEN, UTAH

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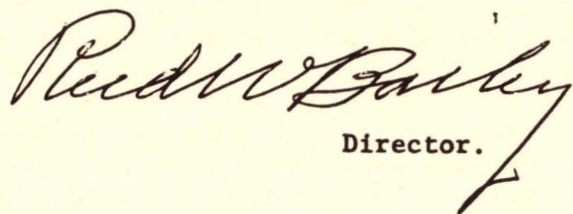
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INTRODUCTION

This annual report of the Intermountain station's activities during 1957 chronicles progress in research made by each of the several divisions. The staff has been alert to the extremely varied demands for study of the numerous problems related to wise management and maximum use of wild land resources of the station's territory. Accounts of research by the several divisions indicate the measure of the year's achievement. For details of this achievement you are invited to study the several sections of this report.

One activity that has been generally engaged in by the station has produced results that are only partially developed in the report. Nevertheless, this activity is fundamentally important to sound, valid, efficient programing: I refer to problem analysis. Its importance stems from the fact that it at once results from and is conducive to enlarged understanding--the most important achievement of scientific research.

In problem analysis no plots are measured, no data sheets are filled; but facts already gathered are assembled, carefully scrutinized, evaluated, and related to each other and to the whole problem. Problem analysis provides comprehensive appraisal of resources and their interrelations, of the processes of analysis, synthesis, and continuing appraisal, increasingly better understanding emerges. Reports dealing with problem analysis will be issued during 1958.


Director.

FOREST MANAGEMENT RESEARCH

The level of forest management varies widely over the 37 million acres of commercial forest land in the area served by Intermountain station. In parts of this area the forest manager is breaking into virgin stands with initial developments. Here he must solve a myriad of problems in converting wild forests to some semblance of management. In other parts of the area, the virgin forests have long since been logged over. There forest management may already be well on the way to a fairly high level. The manager is concerned with problems of obtaining maximum production and utilization from young forests.

This wide range in level of forest management requires an equally wide range of effort in forest management research. However, the problems needing research are so many that the station can tackle only part of them. This imposes responsibility to place our research effort where it will most help the forest manager. We are faced with decisions in placement of research effort between studies that will increase forest production during the next half century and with studies concerned with planting, natural regeneration, and genetics, which will increase forest production only in the very long run.

The present program has aimed for balance. We are engaged in studies of natural regeneration throughout the station area because keeping forest land productive is the first responsibility of any forest manager. Where natural regeneration is most difficult, we are studying methods of planting, with promising results. We have a wide variety of studies concerned with growing stock: how to manage it, build it up, and improve its quality. We are also concerned with genetic improvement of western white pine and ponderosa pine forests.

During 1957 significant progress was made. A cooperative agreement was reached with the University of Idaho for establishment by the Forest Service of a genetics unit at the university. Progress in forest genetics was also marked by hiring of a geneticist, Dr. Lawrence Inman, by the University of Idaho. Stationed at the Boise Research Center, he is developing a better ponderosa pine.

Two items of progress concern our experimental forests. The Bear Run Unit, a 1,200-acre tract of even-aged young ponderosa pine, was added to the Boise Basin Experimental Forest in southern Idaho. This will permit needed studies there in management of second-growth stands. During 1957 logging got under way on the Piquette Creek Experimental Forest in western Montana. This logging begins a program of cuttings that will test various silvicultural and beetle-risk markings, and will provide the experimental forest with a system of utilization roads.

Significant, too, were the close working relationships throughout the station area of forest management research personnel and forest managers in both public and private service. On-the-ground meetings and discussions are bringing the results of research into practice.

The following selected items portray the wide range of effort in forest management research at Intermountain station.

REGENERATION

Studies at Boise Basin Experimental Forest

Studies in artificial regeneration of ponderosa pine on the Boise Basin Experimental Forest were continued during 1957. Further tests of planting by digging holes with a powered auger were tried on four aspects. The importance of tamping was apparent again, and the relative thoroughness exercised by individual planters, as revealed by survival of their plantings was statistically significant. This fact emphasized the need for adequate training of planting crews. Plant competition on this experiment was reduced by hand scalping, which appears to have only doubtful merit in aiding survival of planted trees. These tests showed that 2,000 16- to 18-inch holes could be dug easily per day by two men in ground relatively free of stones using a 5-20 Homelite saw equipped with a power take off.

A start was made on outplanting of ponderosa pine in containers. One study tests two kinds of containers and seasons of planting. Sufficient seedlings were raised in various containers to permit a large-scale test of two methods of planting on three types of ground preparation on two aspects.

Elimination of plant competition to increase survival in plantations is important in regeneration in the ponderosa pine type. Applications of 2,4,5-T to planted areas having a heavy growth of brush, and 2,4,5-T and Dalapon to typical areas of ceanothus and sedge to be planted later, were made and considered successful. This latter test will be followed by site preparation and planting.

Ponderosa Pine Plantations in the Western White Pine Type

When it became evident that blister rust would preclude growing of white pine in many areas in the western white pine region, foresters naturally turned to a valuable species that could be grown on white pine sites. Ponderosa pine seemed to be a possible substitute. Though it was not abundant on the sites normally occupied by white pine, scattered individuals having good form were common even deep within the type. Consequently ponderosa pine was used in reforesting some areas of the white pine type during the early 1930's. Some plantations have grown poorly, possibly because stock used was grown from seed collected in localities having climates differing greatly from those of the areas planted.

A small test planting of white pine from Kaniksu National Forest and of ponderosa pine from Bitterroot National Forest was made in 1937 on Deception Creek Experimental Forest. The species were planted both pure and in mixture on a south slope. Brush competition has been severe. For the first 10 years the trees were all but hidden by ceanothus brush, but since 1947 growth of both species has been good.

First-year survival of white pine was 80 percent as compared to 60 percent for ponderosa pine. By 1942, survival of both species had declined to 50 percent. Since then ponderosa pine mortality has been somewhat more severe than that of white pine. Twenty years after planting, 41 percent of the white pine and 34 percent of the ponderosa pine are surviving.

The height growth rate of ponderosa pine exceeded that of white pine for the first 10 years. Since then, however, white pine has grown faster than ponderosa. At the age of 17 years the average heights of the two species were the same, but at 20 years the average height of the white pine was 16.8 feet compared to 14.6 for ponderosa pine. Height growth of ponderosa pine has been quite uniform over the entire 20-year period. The white pine growth rate, however, has increased during each remeasurement period.

Many ponderosa pines on this steep hillside have been deformed by the downward movement of the heavy snow-pack, but the white pines show very little deformity.

Growth of ponderosa pine planted in different densities of ceanothus brush was investigated in two plots on a west slope of the Priest River Experimental Forest. Survival 15 years after planting on the plot rated as having a 75-percent cover of brush was 21 percent. On the plot designated as having a 25-percent brush cover, 57 percent of the seedlings survived. On both plots, trees in the open survived equally well, but trees in the brush survived better on the plot having the lesser coverage of brush.

Twenty-one years after planting, the trees had suppressed the brush. Subsequent high mortality from unknown causes on the plot that had 25-percent coverage of brush has largely negated the early differences due to brush competition.

Results from the Deception Creek and Priest River ponderosa pine plantations on white pine sites show that while early growth of the trees may be good, their vigor and growth subsequently decline. It is believed, however, that ponderosa pine can be grown successfully on certain white pine sites if care is used in selecting the seed source of the trees to be planted.

Natural Regeneration in the Western White Pine Type

Natural regeneration is generally prompt in the western white pine type on all except the most severe aspects. Twenty years of reproduction records on Deception Creek Experimental Forest following various types of harvest cutting on a wide range of aspects attest the ease of obtaining natural regeneration on good sites and demonstrate the delays that may face the forester on the more severe exposures.

Reproduction on these areas has been measured periodically using a strip-transect method, tallying reproduction on a 4-milacre quadrat basis. A 4-milacre stocking of 65 percent, equivalent to about 1,000 trees per acre, is considered satisfactory.

On the northerly exposures studied, all even-aged silvicultural systems resulted in stocking of all species in excess of 90 percent by the tenth year following logging. Stands cut under a shelterwood system restocked most quickly. Four years after cutting, all shelterwood areas were stocked better than 65 percent, and by the seventh year exceeded 90 percent. Strip clear-cutting on these moist sites has reproduced a stand almost as effectively as the shelterwood system. While stocking on the latter lagged for the first 4 years after logging, it increased to more than 90 percent by the seventh year.

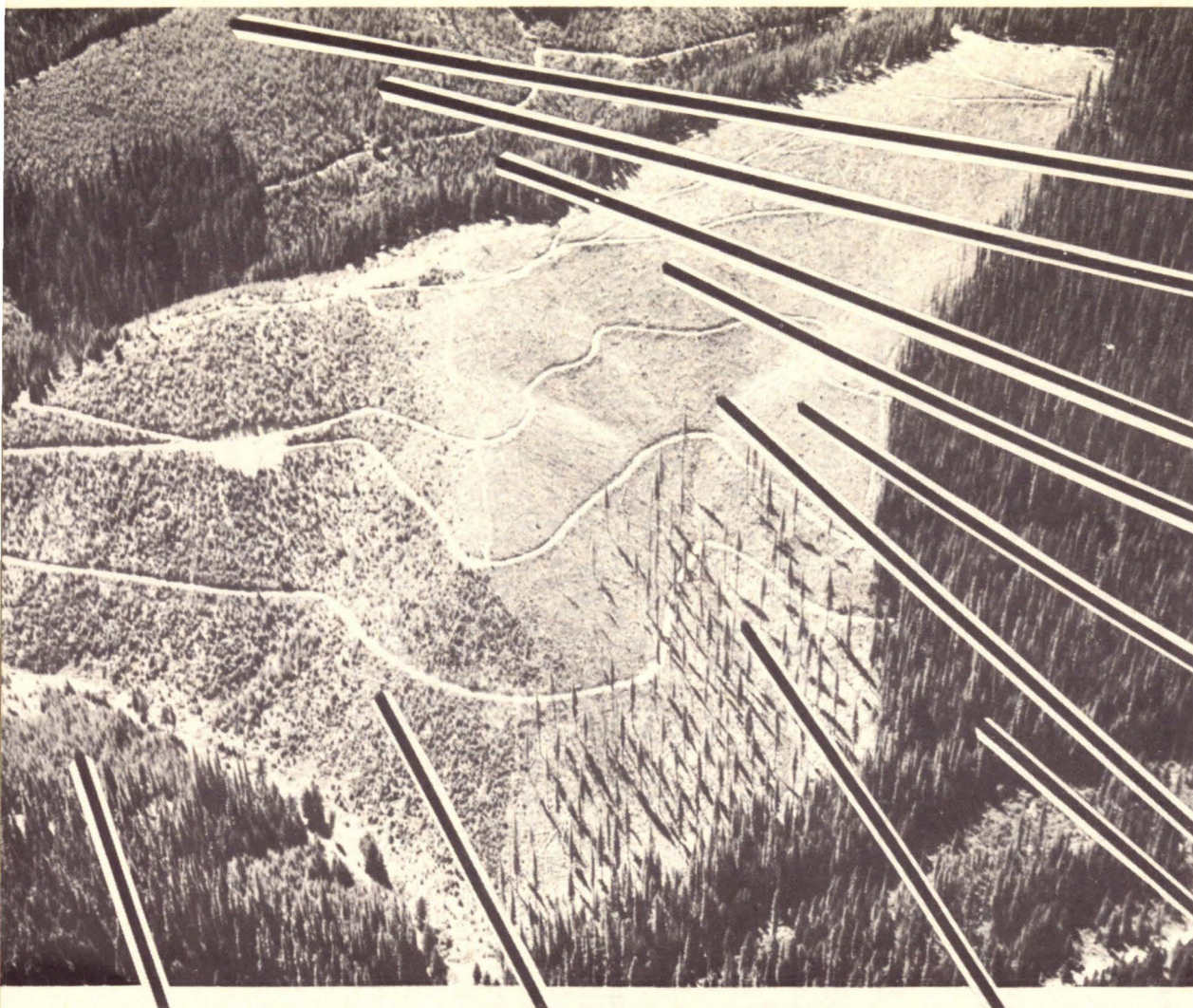
Reproduction has been less rapid on similar cuttings on southerly slopes. From 15 to 20 years have been needed for stocking on most south slope shelterwood and clear-cut areas to build up to a satisfactory level. Pure white pine shelterwood stands on steep south and southwest aspects average 70 percent stocking for all species and 26 percent for white pine 20 years after cutting. On more gentle southerly slopes adequate stocking to all species was fairly prompt and is above 90 percent after 20 years; but white pine stocking is inadequate, with only 40 percent of the 4-milacre units stocked.

Clear-cut strips on steep south slopes have become well stocked to all species in 15 to 20 years, but are only poorly stocked with white pine. Regeneration of a seed tree area having a westerly aspect has met similar delays. Stocking of all species in this area was inadequate when the reproduction was tallied 20 years after logging.

Delay in obtaining reproduction on these severe aspects is further complicated by the fact that the trees now established have a very healthy, dense brush cover as competition. Consequently they probably will grow slowly until they emerge above the brush. In the south-slope shelterwood stands special measures may be needed to establish a stand of white pine equivalent in stocking and composition to those that existed prior to cutting.

Stimulating Cone Production on Ponderosa Pine

A study to determine the effects of girdling and release on cone production of ponderosa pine was started in 1954 on the Bitterroot and Lolo National Forests in Montana. Total number of mature cones by stand age classes and treatment, based on five trees in each category, in first and second crops following treatment is shown in the following tabulation. Both partial girdling and complete knife girdling were exceptionally effective on young (Keen Class 1) trees the first crop following treatment, but the effect dropped off considerably for the second crop.



White pine plantations on clear-cut and control broadcast burned areas.

Test of weeding to free white pine from competition by western hemlock, grand fir, and western larch.

White pine pole stand resulting from 1916 seed tree cutting.

Test of survival, growth, and form of progeny resulting from breeding of blister rust-resistant white pines.

Clear-cutting followed by slashing unmerchantable trees, control broadcast burning debris, and planting to western white pine.

Western white pine plantation spacing test.

Vigor selection cutting.

1910 strip cutting.

Reproduction resulting from 1935 alternate clear-cut and seed strips. Seed strips cut in 1951.

Seed tree cutting.

Figure 1.--Aerial view of a part of the Deception Creek Experimental Forest in northern Idaho. This experimental forest is devoted to research in the management of western white pine forests.

<u>Keen age class</u>	<u>Cone crop</u>	<u>Partial girdle</u>		<u>Knife cut continuous girdle^{1/}</u>	
		<u>Treated</u>	<u>Check</u>	<u>Treated</u>	<u>Check</u>
		<u>Number</u>	<u>Number</u>	<u>Number</u>	<u>Number</u>
1 (50 years)	1st	108	1	106	4
	2nd	14	1	1	1
2 (140 years)	1st	365	316	-	-
	2nd	570	369	-	-
3 (220 years)	1st	633	380	-	-
	2nd	612	224	-	-

^{1/} Age classes 2 and 3 not treated.

While the partial girdling of immature (Keen Class 2) and mature (Keen Class 3) trees appears to have had favorable effect on both first- and second-year cone production, the differences in production between the treated and untreated trees are not statistically significant.

Thus far, release of trees by thinning and by harvest cutting has not increased cone production.

Observations are being continued to determine possible delayed effects of all the treatments.

Natural Regeneration in the Ponderosa Pine Production Study, Boise Basin Experimental Forest

Since a good crop of ponderosa pine seed is expected in the fall of 1958, site preparation to assist natural regeneration on clear-cut groups of the ponderosa pine production study was started in 1957. Production study plans call for scarifying the soil to prepare a favorable seedbed on clear-cut openings just prior to a good seed crop. However, some openings are too steep to be scarified by a tractor without creating a serious erosion hazard. Some of these steep, erodible sites were treated in the fall of 1957 by a method designed to expose mineral soil and eliminate competition without increasing the erosion hazard. A TD-14 tractor with a dozer blade constructed a series of contour strips through the openings. These contour strips were made level or slightly insloping to prevent erosion, to collect moisture, and to change the angle at which the sun strikes the soil surface. The remaining clear-cut openings will be scarified by a hydraulic ripper attached to a crawler tractor in the summer of 1958. If this combination of site preparation and adequate seed does not restock the openings satisfactorily, they will be planted.

INTERMEDIATE CUTTINGS

Lick Creek Study Verifies Pruning Guides for Montana Ponderosa Pine

The Lick Creek study, based upon a paired tree experiment, was designed to investigate effects of crop tree release and pruning. The test, located in Lick Creek drainage on the Bitterroot National Forest, consists of four height-of-pruning classes with 15 pairs of trees in each class. One tree of each pair was randomly selected for treatment. Treatment consisted of removing competing trees to provide a 3- to 6-foot clear space around the crown of each treated tree, and pruning to remove one of the following proportions of live crown: 0, 25, 50, and 75 percent. The study permits a determination of effects of release with no pruning and with three heights of pruning. The trees were dominants in the 4- to 9-inch d.b.h. class and had an average age of 44 years.

Five-year results of the treatments are shown as follows:

<u>Proportion of live crown removed</u>	<u>Five-year growth Inches</u>
None	0.678
1/4	.585
1/2	.526
3/4	.380
Check trees	.617

Although the data show a slight increase in d.b.h. growth on the released trees with no pruning over the check trees, the difference is not significant statistically. Some individual trees showed a marked response to release but others did not. The next 5-year period may show better growth response after the trees have had a longer period in which to take advantage of the additional growing space provided by the release.

A considerable reduction in d.b.h. growth resulted from crown removal in pruning, particularly in the severely pruned trees. Growth of trees in all degrees of pruning varied significantly from that of trees released only. These findings confirm those from California and Oregon studies. In fact, in percentages the studies agree very closely. However, in the Lick Creek study reduction in height growth of the pruned trees was not significant. The response of height growth may not be immediate, but the next 5 years may show a significant effect.

Mortality was insignificant even among the severely pruned trees, for only two trees in the experiment died: they were attacked by insects.

In setting up a guide for pruning it is necessary to determine how much growth reduction one is willing to accept for the sake of quality. One inch per decade for trees in closed stands and under the kind of residual stand

found on the study area can be considered reasonably good growth. Removing up to one-half of the live crown on the study trees failed to reduce growth below this point. However, the crown ratio was reduced to less than 30 percent; this condition could leave the tree in a vulnerable condition. Consequently, a rule of removing not more than one-third of the live crown and retaining a crown ratio of not less than 40 percent should be adequate to retain sufficient crown for reasonably good growth.

Timber Stand Improvement on Boise Basin Experimental Forest

Timber stand improvement following logging on the ponderosa pine production study was continued in 1957. The working plan provides for thinning and improvement cutting in sapling and pole stands followed by crop-tree pruning.

Approximately 80 crop trees per acre were pruned during 1957 on two compartments thinned in 1956. Pruning time studies on these compartments revealed that the crew pruned an average of 25 crop trees per man-day. Height of pruning was about 18 feet.

Three additional compartments were thinned in 1957 according to plan. Thinning methods applied to various compartments of the production study include two intensities of crown thinning and two intensities of thinning from below. Sample plots were installed in each thinned compartment to give information on growth and yield following the four thinning treatments.

MENSURATION

Height-Over-Diameter Curves

Good height-over-diameter curves can be obtained by fitting a straight line to the data on semilogarithmic paper. This method has a distinct advantage over the more tedious method of fitting parabolic curves by least squares. A. Stoffels and J. Van Soest^{1/} in the Netherlands made a study of the various mathematical formulae in use there for fitting height-over-diameter curves. They found that data on Japanese larch and Douglas-fir could be transformed into a straight line relationship when the log of d.b.h. was used, and a simple linear regression line could then be computed. Furthermore, they recommended fitting a freehand, straight line to the data plotted on semilogarithmic paper.

Some comparisons were made between the method of fitting a parabolic curve by the method of least squares and simple linear regressions transforming the data by using the log of d.b.h. Data from ponderosa pine on the Custer National Forest; from lodgepole pine in eastern Montana; from western larch, Douglas-fir, and alpine fir in western Montana; and from Engelmann

^{1/} Stoffels, A., and Van Soest, J. Principele Vraagstukken Bij Proefperken 3. Hoogte regressie (with English summary). Nederlandsch Boschbouw Tijdschrift 25(7-8): 190-199. 1953.

spruce and alpine fir in northern Idaho were used in the comparisons. Standard error of the estimate was computed for each curve fitted by both methods. The data and the computed curves were also plotted to observe the fit. Logarithmic curves fitted the data nearly as well as--better in some instances--the parabolic curves.

The logarithmic curve has the advantage of simpler computational methods. For most purposes the data can be plotted on semilogarithmic paper and a freehand straight line fitted to the points. The linearity of the data can be observed when plotting the points on semilogarithmic paper. If the data appear to be curvilinear, the parabolic curve may give a smaller standard error of the estimate and therefore represent a better fit. However, in the data studied the relationship was linear when transformed by use of logarithms of d.b.h., and curves by the simpler method fitted the points as well. Where large numbers of height-over-diameter curves need to be fitted by objective methods, the logarithmic curve saves much time.

Lodgepole Pine Growing Stock Study

During 1957 the station started a new study on a problem which is of vital concern in the silvicultural management of lodgepole pine; namely, optimum stocking. This study is the first phase of an attempt to determine stocking levels for best growth in pure, even-aged stands of different age classes up to about 120 years. An interim goal is the preparation of improved site classification and yield tables for this species.

The first step in this study is establishment of a series of small permanent plots in lodgepole pine stands with a wide range of density and growing on areas of different site quality. Most of the plots are to be located on national forest land in Montana east of the Continental Divide. Supplementary data may be gathered from national forest lands in western Montana, western Wyoming, and eastern Idaho. First plot installations are being made on the Lewis and Clark National Forest in age classes 21-30, 71-80, and 81-90 years.

Because a similar problem exists for western larch, much of the knowledge gained in this study will be valuable in extending study to larch.

Board-foot Growth of Ponderosa Pine Following a Second Cutting

Studies in western Montana provide preliminary growth estimates for ponderosa pine following a second harvest cutting. The area in which the second cut was made is a 223-acre tract on the Bitterroot National Forest in Montana's earliest Forest Service selectively logged ponderosa pine stand. The initial cut was made about 1909. Average site index is 74 feet at 100 years. Table 1 shows the net annual growth per acre by reserve stand volume after the second cut.

Growth was best after the second cut where the largest reserve stand was left, as was expected. A similar relationship between reserve volume and growth has been found in many other ponderosa pine studies following initial cuttings.

Table 1.--Average annual growth per acre by reserve stand volume during 5-year period following second cutting

Reserve stand volume	Residual timber ^{1/}		Ingrowth	Net annual volume growth per acre
	Growth	Mortality		
<u>Bd. ft.</u>	<u>Bd. ft.</u>	<u>Bd. ft.</u>	<u>Bd. ft.</u>	<u>Bd. ft.</u>
2,031	106	5	47	148
5,768	117	0	28	145
8,000	97	8	11	100
12,441	231	3	8	236
<u>2/</u> 8,121	<u>3/</u> 133	5	<u>4/</u> 16	144

^{1/} Trees 9.6 inches and larger.

^{2/} Weighted average on 223.3 acres.

^{3/} About 20 percent in Douglas-fir.

^{4/} About one-half of ingrowth on Douglas-fir.

Ingrowth varied inversely with reserve volume. The less the reserve volume, the greater the amount of ingrowth. This relationship reflects the treatments given the stand in both the first and second cuttings. Most of the ingrowth during the recent 5-year period is in trees that became established after the initial cut; the second cut provided the release needed for sustained rapid growth. Younger trees also have responded well to release; for this reason a virtual wave of ingrowth can be expected during the next 10 to 15 years. The low mortality throughout the area shows that reserve trees were properly selected.

The stand is in excellent growing condition and during the next 15-year period, after which a third cut is planned, should continue to add board-foot volume at a rapid rate.

Near-Merchantable Ponderosa Pine Trees are Produced
by Plantations in 50 Years in Western Montana

Data collected during a recent cooperative porcupine damage survey of ponderosa pine plantations in Region 1 provided opportunity to study the growth of crop trees. Since the survey included only crop trees, full stand stocking information is not available. However, the progress of crop trees is interesting to foresters in assessing the future sawlog production in plantations. Stocking, on the basis of the survey, can be considered moderate. The point system was used to select crop trees for examination, and on this basis at least 100 to 140 well-distributed crop trees (mostly dominants) are present. The plantations were classified as to site index, and curves of average diameter and total height of trees were made.

Table 2 presents average total heights and diameters of crop trees by age of plantation and site index. On sites of index 70 the crop trees are just entering the 11-inch d.b.h. class 50 years from planting.

Table 2.--Average diameter breast high and total height of crop trees by age of plantation and site index (western Montana)

Age (years)	Site index							
	40		50		60		70	
	Diameter	Height	Diameter	Height	Diameter	Height	Diameter	Height
	Inches	Feet	Inches	Feet	Inches	Feet	Inches	Feet
15	--	--	0.6	5	0.8	5	0.9	6
20	1.3	7	2.0	9	2.7	11	3.2	14
25	2.2	9	3.2	13	4.1	16	4.8	20
30	2.9	11	4.1	16	5.2	21	6.2	26
35	3.5	13	4.9	18	6.2	24	7.4	32
40	4.0	15	5.6	20	7.2	27	8.5	36
45	4.3	16	6.2	22	8.0	30	9.6	40
50	4.6	18	6.7	24	8.8	32	10.6	42

Standard error of estimate: D.b.h. = 0.831 inch
Total height = 2.5 feet

We could, assuming 60 percent as much diameter growth for the next 50 years, expect that at age 100 years^{2/} the crop trees will average at least 16 inches in diameter. If we assume that an average of 100 crop trees per acre survive until that time, the volume in 100 years would be about 15,800 board feet. This is slightly larger than the 13,100 board feet shown in the normal yield tables^{3/} for site index 70 at 100 years.

The average crop tree diameters reached in the lower site classes by age 50 years are considerably smaller; consequently these trees will require longer time to reach merchantability. Thus, where plantations are made primarily for timber production, reliable methods are needed for selecting planting sites to assure good volume production within reasonable rotation periods.

^{2/} 100 years has been selected as a reference point only and should not be construed as a recommended rotation age.

^{3/} Meyer, Walter H. Yield of even-aged ponderosa pine. U. S. Dept. Agr. Tech. Bul. 630, 60 pp., illus. 1938.

Growth of Western White Pine Plantations

Ten years of growth records on two sets of plantation plots located on the Coeur d'Alene National Forest show that, on the average, plantations of western white pine are producing in excess of what could be expected from fully stocked natural stands on similar sites. The sample plots include one set in a stand 36 years old from seed with site indices ranging from 60 to 85, and another set in a stand 43 years old from seed with site indices from 63 to 80.

Both stands were established on areas denuded by the 1910 fire. The area now occupied by the 36-year-old stand was reburned in 1919 and planted in 1924. Because of the double burn, the stand is nearly pure planted white pine. By contrast the 43-year-old plantation, which was not preceded by a second burn, contains a small component of naturally seeded Engelmann spruce, lodgepole pine, western larch, and alpine fir.

At their present ages, these plots average 27 percent more volume and 21 percent more basal area than normal second-growth stands having the same site indices. This greater cubic-foot and basal area production has been put on 38 percent fewer stems than are indicated for equivalent normal stands. The mean stand diameter of the plantation is 6.3 inches, compared to a normal of 4.4 inches, or a difference of 1.9 inches. When only the dominant and co-dominant stand is considered, the difference is 0.6 inch.

Apparently, as a result of uniform wide initial spacing of trees, the plantations have gotten off to a faster start than fully stocked natural stands. How long these stands can maintain their high initial growth rates may depend on opportunities for early thinning.

Plantations of western white pine have three advantages over natural stands: they can be started promptly without depending on occurrence of good seed years; they have a high initial growth rate that further augments their prompt start; and they have a high proportion of the most valuable species.

GENETICS

Breeding Blister Rust-Resistant Western White Pine of Good Growth and Quality

Development of a blister rust-resistant western white pine is a joint project between Blister Rust Control, Region 1 of the Forest Service, and Intermountain station. Rust resistance aspects are the responsibility of Blister Rust Control. Major accomplishments in the vigor-quality phases, which are a part of the station's research program, are described below.

1. As mentioned in previous reports (1955 and 1956) a series of tests designed to stimulate flowering in western white pine has been started. Most of these have been successfully established, and we can look forward to

information that will be valuable for use in seed orchard establishment within a few years. One of the tests, that of applying cultural treatments to young trees, has already begun to show results. In this test 6-year-old trees were planted in the fall of 1955. The cultural treatments including watering, cultivating, and fertilizing (a 14:14:14 mixture of commercial fertilizers) are being applied yearly, both singly and in all possible combinations. Second-year height growth as measured in the fall of 1957 is tabulated below. The data are averages of 4 to 8 trees for each treatment.

<u>Treatment</u>	<u>Height growth during 1957 Feet</u>
None	0.19
W (Watered)	.26
C (Cultivated)	.33
F (Fertilized)	.38
WC	.40
WF	.60
CF	.57
WCF	.53

An over-all analysis of variance of the data showed significance at the 5-percent level. The trees given any kind of treatment grew faster than the controls, and the apparent effect of fertilizing was greater than either of the other single treatments. However, the greatest response was obtained when fertilizing was coupled with either watering or cultivating or both. The average growth rate of trees receiving either of those three combinations (WF, CF, or WCF) was about three times as great as that of the controls. Apparently the effects of fertilizing were largely additive to either or both of the other two treatments. Watering and cultivating, on the other hand, showed only a slight additive response when used together without fertilizer and none at all when used together with fertilizer. Apparently the main benefit of cultivating resulted from reduction in competition with other vegetation for available moisture. If that is true, the response may change in an unusually dry season, and watering may show greater effect. However, cultivating appeared to improve the general vigor of plants, especially in the presence of fertilizer. Fertilizing caused heavy weed competition, but without cultivation the fertilized trees often appeared to have smaller and less vigorous crowns than trees both fertilized and cultivated.

The particular cultural treatment best suited to stimulate vegetative growth may not be the best for stimulating early and abundant flowering. Some early information on this point may soon be obtained from another test already established in which the full cultural treatment described above is being applied to trees 10 to 15 years old. Further tests, in which the fertilizer mixture will be varied, are planned.

2. A preliminary experiment in selective fertilization conducted during the years 1954-56 has led to the tentative conclusion that western white pine trees are largely cross-pollinated under natural stand conditions. The importance of this subject stems from the fact that the potentiality for selfing in seed orchards, where clones or closely related trees are used, may be magnified and that selfing usually results in inbreeding depression. The preliminary experiment was concerned with the relative ability of a self-fertile tree to produce germinable selfed seed when its pollen must compete with that of another tree.

In the spring of 1957 this work was extended in an attempt to determine the nature and extent of selfing that may be expected under seed orchard conditions which entails several different facets. Pollinations made for these new tests were apparently successful, but of course several more years will be required for completion. A report covering the earlier work has been submitted for publication in Silvae Genetica.

3. During 1957 a technique for evaluating tree competition around western white pine selections was tried. The method was merely an application of the variable plot-radius cruising technique, using a wedge prism having a basal area factor of 10.^{4/} The method was applied to a total of 153 selections (25- to 60-year-old dominants and codominants) situated in stands of varying density. The selection was the center of the "plot" and all other live or recently dead trees whose stems overlapped when viewed through the prism were counted. The count of trees thus obtained was then converted to basal area and used as a measure of competition.

This method was found to be fast and generally satisfactory. The competition data, along with other measurements previously obtained, were used in an analysis to determine effects of competition. Results showed that although increasing competition significantly increased total height, decreased d.b.h., and decreased stem volume, last 10-year periodic annual height growth was not significantly affected. The apparent effect on total height was explained on the basis of more intensive nongenetic selection for early growth rate in dense as compared to open stands. The findings support previous beliefs that last 10-year periodic annual growth is superior to mean annual growth for use in tree selection work in young western white pines.

Racial Variation in Ponderosa Pine

Recent examination of a 45-year-old test of racial variation in ponderosa pine showed that only minor changes in performance have occurred during the past 20 years. Progenies from localities nearest the planting site have generally continued to be superior in growth rate and survival to progenies from the more distant localities. This test, begun in 1911, consists of a planting on the Priest River Experimental Forest of seeds from 21 different

^{4/} Bruce, David. A new way to look at trees. Jour. Forestry 53: 163-167. 1955.

sources of ponderosa pine, representing most of the range of this species. A report in 1937^{5/} proved the existence of races in this species and cautioned against the use of seed from outside of the North Plateau region (generally eastern Washington and Oregon, northern Idaho, and western Montana) for use in planting in northern Idaho.

The ten progenies within the North Plateau region now average 37 percent greater in total height (using the tallest one-third of the trees in each progeny) than progenies from regions to the east and south. The single surviving progeny from the North Pacific region (Siskiyou) has grown fully as well as or better than progenies from local sources. However, survival of trees from that progeny has been very poor. A severe frost in 1924 killed most of the Siskiyou trees and all of those from the other North Pacific progeny, namely Shasta.

The most recent data from this test are being analyzed in detail to study the relationship of growth performance at the planting site to climatic factors of the source locality. The Pacific Northwest station has conducted a similar study of this species in their region, and it is planned to coordinate recent data from the two studies and to report jointly when completed.

Field Tests of Ponderosa Pine Hybrids

For several years this station has been field-testing pine hybrids developed by the California Forest and Range Experiment Station. In all of these crosses both the seed parents and the pollen parents were not native to Montana. In one series, ponderosa pines from a California source were crossed with pollen parents of the scopulorum variety of the pine from Colorado, and the progeny were planted in two localities in Montana. Along with these hybrids several lots of wind-pollinated ponderosa pine from California and two wind-pollinated lots from Montana were planted as controls. A single lot of hybrids between ponderosa pine from California and pollen parents of Apache pine (Pinus engelmannii) was also planted.

Five years after outplanting, none of the nonnative control trees and the Apache pine hybrids survived. Mortality was also extremely high among all other lots planted on the eastern Montana site, where only 5½ percent of the trees survived. Losses at this site resulted mainly from drought.

Average total heights of the surviving hybrid and native control lots in the western Montana plantation are shown in the following tabulation. The comparison shows little difference in average diameter between hybrids and controls. All the hybrids are shorter than the controls and are slightly narrower crowned. Note that both control lots are considerably taller than the hybrids. Because of the extremely low survival, the eastern Montana plantation has been abandoned. The western Montana test will be continued however.

^{5/} Weidman, R. H. Evidences of racial influence in a 25-year test of ponderosa pine. Jour. Agr. Res. 59: 855-887. 1937.

<u>Seed parent</u>		<u>Pollen parent</u>	Av. total height <u>Feet</u>
<u>P. ponderosa</u> (Eldorado 2,800 ft. elev.)	x	<u>P. ponderosa</u> v. <u>scopulorum</u> (Colorado)	0.61
<u>P. ponderosa</u> (Eldorado 4,000 ft. elev.)	x	<u>P. ponderosa</u> v. <u>scopulorum</u> (Colorado)	.66
<u>P. ponderosa</u> (Eldorado 5,400 ft. elev.)	x	<u>P. ponderosa</u> v. <u>scopulorum</u> (Colorado)	.84
<u>P. ponderosa</u> v. <u>scopulorum</u> (Helena)	x	wind	1.04
<u>P. ponderosa</u> (Kootenai)	x	wind	1.16

FOREST DISEASE RESEARCH

Forest Disease Research attained division status at the Intermountain station in 1957, when a division chief was added to the staff in September. During the year the station's soil scientist, who had been studying pole blight of western white pine, transferred from the disease research staff to the Division of Watershed Management Research in Ogden.

The division's accomplishments and activities during the year include: the definite confirmation of a former lead to the cause of pole blight; the determination that permanent long-period weather stations will aid in predicting the success of white pine blister rust control operations on surrounding control units; dispersal of the pine-infecting spores of blister rust was simulated by means of silver iodide particles; mortality of ponderosa pine from the Elytroderma needle blight was summarized for a 7-year period on study plots in southern Idaho; experimental results to date on control of dwarf-mistletoe by chemical sprays were summarized; dwarfmistletoe surveys were completed on two more national forests; Poria weirii was found to be causing considerable tree mortality in the Inland Empire; and the forest disease staff produced 10 technical publications in 1957.

POLE BLIGHT OF WESTERN WHITE PINE

A previous lead to the cause of pole blight was strengthened in the past year's research on this disease. The 1957 results strongly indicate that pole blight is a physiological disease brought on by moisture deficiency in the soil. Soils on 353 plots have been studied since 1954, and no stands affected with pole blight have yet been found on soils having more than 5 inches of available moisture storage capacity in the upper 3 feet of soil, but the disease occurs commonly on soils having only 0.7 to 5.0 inches.

Soil Survey

An extensive soil survey of 61 white pine pole stands, 50 to 90 years old, located throughout the western white pine type in western Montana, northern Idaho, and eastern Washington was carried out to determine whether any stands affected by pole blight were growing on deep soils (available for root growth and penetration for 36 inches or more) with high available moisture storage capacities (more than 5 inches in 3 feet of soil). Data were collected on 319 plots located in these stands. While many of the data must still be analyzed, present conclusions are that much greater opportunity is provided for uniform root growth and distribution in healthy plots, particularly those in healthy areas. Even though both uniform root growth and greater available moisture storage capacity are probably highly significant in determining the health of a stand, adequate moisture distribution and availability from sources other than direct precipitation are also important. Soil moisture recharge is much more limited by shallow soils in diseased stands than in healthy stands in either diseased or healthy areas.

Artificially Imposed Drought Experiment Extended to the Clearwater Area

Another plot was established to determine the effects of artificially imposed drought on growth. A plastic covering, similar to one used and reported in 1956, was installed on a plot located in a 60-year-old white pine stand in the Clearwater area. This area lies outside the present boundary of pole blight infection. The purpose is to study the effect of moisture stress on white pine root growth and mortality.



Effects of an artificially imposed moisture stress on white pine are being determined as part of the pole blight research program. A shelter, tree caps, and perimeter trench aid in intercepting rainfall and soil drying.

WHITE PINE BLISTER RUST MICROCLIMATE

Whether an area constitutes a high hazard to the success of control measures applied to blister rust depends largely upon the microclimate on that particular area. Where the microclimate is exceptionally favorable for rust development and spread, control of the rust is impossible by standard procedures. The ultimate objective of microclimate studies now being made is to define these high hazard areas, make them readily recognizable, and to locate and delineate them.

Use of Permanent Long-Period Weather Stations

To apply the weather records of long-established stations to surrounding study areas it is necessary to be able to correlate those records with micro-climate measurements on the study areas. To apply the chances for rust development determined for long period stations to nearby areas, information is needed on variation of moisture and temperature as topography and vegetative cover change. To provide this information, the exploratory study of variation in summer temperature and humidity made during 1956 was extended to include additional classes of vegetative cover, position with regard to terrain, direction of exposure, and elevation. Observations were made at 219 stations on four different types of areas in the Kaniksu National Forest. Temperatures and humidity at the various stations are being compared with those at control stations located in the open on level terrain. Differences are consistent enough in most areas to indicate that a few weeks of observation are sufficient to establish reliable comparisons between various sites and nearby long period weather stations.

Fifty-nine pairs of the stations were established under like vegetative and topographic conditions to determine the variation in temperature and moisture between similar sites. Considerable variation, particularly in maximum temperature, was observed between pairs of stations on the similar sites. Greatest variation was on upper slopes of knolls. Differences in maximum temperatures between stations on three knolls having the same elevation, aspect, slope, and vegetation ranged from -7° to $+14^{\circ}$ F. On localities where such variation is likely, additional temperature observations may be needed in each working unit to determine relationships of temperature and humidity to long period stations and from these relationships chances for rust on the site. On localities where variation is not expected to be excessive, chances for rust determined for the long period stations can be extended directly to the site from a knowledge of its terrain and vegetative class.

The mobile atmospheric research laboratory of the Forest Fire Laboratory in Missoula integrated the observations at the fixed stations established in the upper Kalispell Creek area.

Simulated Spore Dispersion

The Forest Fire Laboratory cooperated in an attempt to simulate spore dispersion by means of silver iodide particles in the upper Kalispell Creek area. Upper Nuisance Creek, a fork of this drainage, located just south of a low pass on a ridge connecting Diamond Peak and Kalispell Rock, is a blister rust problem area. The central question to be answered is: Are blister rust spores released from ribes on the northwest slope of Diamond Peak (outside of the control area) carried through the pass into the upper Nuisance Creek area where they infect pines? Petit Lake, at the north end of the pass, is considered to be a possible source of moisture. When the lake is warmer than the air, convective currents over the lake provide a means of carrying spores, brought down the slope of Diamond Peak by drainage winds, to higher levels. If air flow from the north prevails aloft, the spores might be carried through the pass into the Nuisance Creek area.

A silver iodide generator was operated on the northwest slope of Diamond Peak on a clear cold night favorable for the proper drainage winds, convective currents, and the northerly flow described above. The plume of silver iodide particles was soon detected in the pass by means of a cold chamber and later was detected in upper Nuisance Creek. This brief experiment indicated that particles can be carried through the pass as hypothesized. Further study will be made under conditions favorable for spore dispersion in this area. The experiment also demonstrated the usefulness of silver iodide particles as a means of determining spore distribution patterns from a known source when actual spores are difficult to trap or identify, are few in number, or are released from so many sources in the area being studied that origin of those trapped would be doubtful. Further comparison will be made of the relative size and rate of fall of silver iodide and white pine blister rust spores to determine the applicability of results obtained from a study of silver iodide dispersion to a spore dispersion problem.

PONDEROSA PINE BLIGHT

The Elytroderma deformans leaf and twig disease of ponderosa pine, although widely spread throughout the station's territory, continues to remain epidemic only on localized areas where it has been severe for several years. Data obtained in 1957 showed but very little decline in intensity of the disease from that recorded in 1956. Intensity of the blight epidemic, however, is now far below the peak of 1950 and 1951.

Damage Studies

Studies were started in the Intermountain region in 1951 on six plots established in blighted stands, and data have been taken annually on them. The main purpose of these studies is to determine the rate of mortality and extent of volume loss from the blight as a basis for planning salvage logging in affected stands. The mortality that has occurred to date on the plots is summarized in table 3.

Table 3.--Seven-year loss through mortality from Elytroderma needle blight, by stand types, on sample plots in affected ponderosa pine stands on the Boise National Forest, 1951 to 1957, inclusive

Stand description	B a s i s			M o r t a l i t y			
	Plots	Trees	Volume	Trees		Volume	
	Number	Number	Board feet ^{1/}	Number	Percent	Board feet ^{1/}	Percent
Virgin, mature	3	76	72,140	12	15.8	5,890	8.2
Mature, cutover	2	57	53,370	6	10.5	2,970	5.6
Second growth, immature	1	28	19,110	7	25.0	3,380	17.7
All stands	6	161	144,620	25	15.5	12,240	8.5

^{1/} Scribner Decimal C scale.

All ponderosa pines on all plots were infected. Infection occurred sometime prior to plot establishment in 1951. To date 15.5 percent of the total 161 trees originally on the plots have died; however, the volume loss is only 8.5 percent. Therefore, mortality has occurred in the smaller size classes. Mortality in second growth has been about nearly 3 times that in mature or cut-over stands.

Twenty-three of the 25 pines that succumbed were in Keen classes 2C, 2D, 3C, or 3D. No mortality has occurred in class A trees. Increment of these pines had been greatly reduced for 15 to 40 years prior to their death. There thus appears to be a relationship between tree vigor or condition and mortality. Further evidence of this relationship is indicated by the fact that all mortality has occurred in trees originally classed as fair, poor, or very poor--most of it in the latter two classes. Death has come slowly, and some trees originally recorded in those classes are still alive. Trees in poor condition never seem to improve noticeably, whereas trees in good or excellent condition when plots were established are not as heavily infected now as they were in 1951. Salvage logging of severely diseased trees is therefore suggested as a means of reducing losses in affected stands.

Information on seedlings and saplings has been obtained from a separate plot established in 1951 within a severely blighted stand of mature ponderosa pine. The plot contained 80 trees, 25 of which were infected. They ranged from 8 to 21 feet in height, but the 55 uninfected trees ranged from 0.6 to 5.1 feet. Between 1951 and 1957, inclusive, 10 of the infected trees (height range 9 to 20 feet) died. All of these except one were either damaged by porcupines, suffered snow bending, or both. Since 1951 only two additional trees have become infected. Both are badly suppressed individuals about 1.5 feet in height and between 12 and 15 years old. The remaining uninfected trees are all vigorous and have maintained a good annual growth rate.

EXPERIMENTS IN CHEMICAL CONTROL OF DWARFMISTLETOE

The dwarfmistletoes Arceuthobium spp. occur in most coniferous species throughout the station's territory and are the most damaging pathogen in some of them. Reduction of losses caused by these parasitic plants presents the most important pathological problem in silvicultural management of young stands.

Direct control by use of chemicals particularly appeals to many forest managers because they believe it would simplify control measures. Chemical control experiments have been undertaken at several western stations in the United States and at Canadian Laboratories, and many chemicals have been tried on several species of dwarfmistletoe involving various species of host trees.

Control Experiments in Lodgepole Pine Dwarfmistletoe

Experiments on chemical control of the lodgepole pine dwarfmistletoe Arceuthobium americanum, started in the Intermountain region in 1952, have been continued through 1957. These have been so-called screening tests conducted on plots about one rod square in lodgepole pine reproduction to determine whether any of the test materials would be toxic to the parasite without seriously injuring the pine host.

A total of 17 different materials, mainly so-called herbicides, has been used. Also mixtures of two or more materials were tried, and oil in small amount was added to some solutions. These materials were sprayed on both the dwarfmistletoe plants and the pine foliage by 3- to 5-gallon capacity pressure-type sprayers.

To date 127 separate tests have been conducted on the same number of plots. No material yet tested, or combinations of materials, has given a satisfactory kill of both the aerial portions and the endophytic or so-called root system of the dwarfmistletoe plant. Several materials killed the aerial portions, but resprouting from the endophytic portion occurred in time. Three materials retarded resprouting for a maximum of 2 years following application.

Spraying has been conducted in spring, summer, and early fall. Apparently the stage of vegetative activity of the dwarfmistletoe plant is important in timing the spraying. Spring spraying, when seasonal growth of the plant is just starting, has been less effective on aerial portions of the parasite than summer spraying, when growth activity was greater. A much poorer kill of the aerial portion of the dwarfmistletoe was obtained when soil moisture was low than when it was high.

Oil emulsions were consistently toxic to the host; the oil not only burned pine foliage, but killed some small trees.

Only two materials have been tested on Arceuthobium douglasii, the dwarfmistletoe in Douglas-fir. Neither of these gave a satisfactory kill.

FOREST DISEASE SURVEY

A small allotment is available for disease surveys in Region 1, but no money has been available for similar surveys in Region 4, where such surveys are urgently needed.

Survey of pole blight occurrence was continued in Region 1, but highest priority in disease surveys there is for detection and appraisal surveys of the dwarfmistletoes. Distribution, intensity, and damage appraisals of dwarfmistletoes were started in the Inland Empire in 1956. Each national forest was designated as an area unit, and its ranger districts as subunits for this survey.

Dwarfmistletoes

Distribution and damage appraisal surveys of the dwarfmistletoes were continued in 1957. Roadside reconnaissance has now been made in four national forests in the Inland Empire and a sample strip survey with randomized plots in two of these forests.

On all four forests combined, the status of dwarfmistletoe was recorded along 2,046 miles of roadside strip, using one-tenth mile as the basic unit for determining occurrence and abundance. In the plot survey, 600 1/5- and 1/10- acre plots were established in merchantable stands of Douglas-fir and larch in the Colville and Nezperce Forests. Results of these surveys are shown in table 4.

Table 4.--Incidence of dwarfmistletoe recorded from roadside and plot surveys by species in four national forests in the Inland Empire

National forest	Roadside survey ^{1/}				Plot survey ^{2/}	
	Douglas-fir	Western larch	Lodgepole pine	All species	Douglas-fir	Western larch
				<u>P e r c e n t</u>		
Colville	76	86	25	77	80	92
Nezperce ^{3/}	62	79	53	70	78	92
Coeur d'Alene	--	64	--	--	--	--
Kootenai	--	70	--	--	--	--

1/ Based on distance traveled through infested areas, expressed as a percentage of the total distance traveled, by species.

2/ Based on the infected board-foot volume (Scribner), expressed as a percentage of the total board-foot volume, by species.

3/ Only the west half of the Nezperce Forest was surveyed.

The roadside survey showed no great difference in abundance of larch dwarfmistletoe in the overstory of mature stands, cutover stands, or stands of fire residuals. However, incidence of Douglas-fir dwarfmistletoe appears to be greater in cutover stands than in other stand types containing merchantable overstory trees. Dwarfmistletoe was 2.4 to 7.1 times as abundant in pole-sized stands occurring as an understory than in pole-sized stands having no overstory. Infection in western larch stands in the Coeur d'Alene and Kootenai Forests was not correlated with composition of larch; dwarfmistletoe was as common in stands having low larch composition as in stands having a moderate or high percentage.

More than one million board feet of merchantable-sized Douglas-fir and western larch were contained in the 600 plots on the Colville and Nezperce Forests. Trees containing 83 percent of this volume were infected--79 percent of the Douglas-fir volume and 92 percent of the larch volume. Trees recently killed by the dwarfmistletoes contained 7 percent of the total Douglas-fir volume and 13 percent of the total larch volume. This does not

represent the total dead volume--only that in which dwarfmistletoe was considered to be a major factor contributing to death. In the nonmerchantable stand on the plots, 44 percent of the Douglas-fir stems in the understory and 61 percent of the larch stems in the understory were infected with dwarfmistletoe

Some forest managers know the destructiveness of dwarfmistletoe, but many are only convinced of its seriousness and take action to cope with the disease when overwhelming evidence of its damaging effect is presented. The results of dwarfmistletoe surveys to date have supplied information that points out the magnitude of the dwarfmistletoe problem.



Mature Douglas-fir stand on the Colville National Forest showing trees with entire crowns broomed from heavy dwarfmistletoe infection.

Poria weirii

The root disease Poria weirii, heretofore considered an important root pathogen of Douglas-fir only on the Pacific Coast, has been found to cause considerable mortality in the Rocky Mountain type Douglas-fir and several associated tree species on the Coeur d'Alene National Forest and in several centers of infection on other national forests within the Inland Empire. A survey to determine the extent and magnitude of losses from this disease should be made.

FOREST INSECT RESEARCH

During 1957 the three-phase program of research, insect surveys, and technical assistance on control projects carried on at the station progressed satisfactorily.

Major emphasis in research was placed on studies of spruce budworm and Douglas-fir beetle with additional limited work on Black Hills beetle, spruce mealybug, larch insects, white fir needle miner, black pine leaf scale, the risk-rating and selective logging of ponderosa pine as a means of indirect control of western pine beetle, and improvement of insect survey techniques.

Insect populations remained at a fairly high level and imposed a heavy workload for station entomologists. Large-scale control projects against spruce budworm and bark beetles required technical assistance during the planning stages and execution of control in the field.

It is not intended to present details of all of the research of the division program in this report. Items have been selected from the three major fields of activity to illustrate the progress made during 1957.

RESEARCH

Douglas-fir Beetle

Studies of the Douglas-fir beetle, Dendroctonus pseudotsugae Hopk., started in 1956 in southern Idaho were continued through 1957. Attention was given to population sampling and the cataloguing of natural control organisms and assessing their abundance and effect.

Accurate estimates of populations are essential to the program, but sampling of standing trees poses a problem of mechanics and manpower when large numbers of samples are required. Last year it was determined that samples midway of the infested length of the bole gave more satisfactory results than those at the extreme lower and upper ends. Further study indicated a broad middle zone in which equally good results were obtainable. The lower limit of this zone was between 9 and 12 feet from the ground. Application of this finding obviates the need to fell trees or climb to excessive heights for sampling.

Knowledge of brood survival is important in determining trends in populations. Brood survival was measured with good results by rearing infested slabs (p.27). Slabs have several advantages over other methods: (1) grouping of material in one location permits daily observation and collection of insects emerged from slabs, (2) larger numbers of samples can be handled than by attaching cages to trees or logs, (3) mites attached to emerged beetles can be recovered for study, and (4) cages containing slabs can be protected from damage that may befall screen field cages.

Accurate determination of egg density is essential for reliable estimates of initial beetle populations as a base for determining relative survival and mortality at intervals during maturation of the brood. Measurements of 274 egg galleries averaged 7.93 eggs per inch. Number of eggs and gallery length had a straight line relationship.

Observations of biological factors that effect reduction in beetle populations have produced interesting and significant facts:

1. Mites are found in staggering numbers on emerged Douglas-fir beetles; two beetles each had 238 immature mites clinging to them, and on 750 beetles a total of 20,000 mites was recorded. While these mites may not affect the life of the adult beetle, the transport of the mites by the adult beetles aids in their distribution. Evidence points to mites as important predators of beetle eggs.
2. The seasonal history of Enoclerus sphegeus, a predator on Douglas-fir beetle, proved to be different from that reported from studies of other Dendroctonus species.
3. Observations of low-level infestations in southern Idaho where previous populations had been at epidemic level and very active infestations in southern Utah provided interesting contrasts. In Utah, infested bark contained more brood and relatively fewer predators. A parasite abundant in Idaho was almost absent in southern Utah.



Tree climbing to obtain samples of the Douglas-fir bark beetle. This method enabled the sampling of optimum stem locations without the need for falling the trees.

Through continued study of the interrelationships of the beetle, its natural enemies, and its environment, the division plans to determine factors responsible for variations in populations and tree-killing. Such knowledge may lead to the development of methods of lessening damage to extensive Douglas-fir forests.

Spruce Budworm

Phases of research on spruce budworm are divided between the Missoula laboratory and the Boise Research Center. At Boise the main effort is on studies of populations and subsequent damage; at Missoula the primary objective is to determine biological factors affecting populations.

During 1957, the first year of research at Boise on populations and damage, the prime consideration was development of sampling techniques for collections of budworm at various developmental stages during the seasonal history of the host.

Bole samples from infested trees produced second instar larvae under laboratory conditions early in the winter after temperature conditioning. Field-collected material stored out of doors for several months was subjected to -25° F. for varying periods of time prior to rearing tests. Similar lots were subjected to 40° F. in a similar manner. The best results were obtained by subjecting bole sections to a temperature of -25° F. for 8 hours. More critical work involving three temperature treatments

Slabs containing Douglas-fir beetle brood were obtained in the fall with a power saw for convenient rearing of overwintering adults.



and a greater range of times of exposure is under way at Missoula. This study utilizes bole samples and artificial hibernating sites of gauze. Percentages of recovery can be determined from the artificial hibernaculae. The advantage of forcing hibernating larvae from their hibernaculae out of season lies in the resulting ability to estimate populations expected in the spring well before normal emergence. The results bear directly on planned control projects and upon studies of populations.

Analysis of samples taken from 15-inch twigs clipped at three levels within the crowns of Douglas-fir trees showed that midcrown sampling furnishes reliable estimates. Sampling of larval instars from early spring until pupation at four periods showed no significant difference between the first three collections; but there was significant difference between these three and the fourth. Therefore, in sampling budworm larvae two population standards should be used: one for early instars and one for mature larvae.

Studies of the bionomics of the spruce budworm in Montana were continued during 1957 with the addition of study plots in three areas where collections made throughout the season are examined for evidence of biological factors that effect reduction of populations. Similar data were taken during studies in southern Idaho.

Glypta fumiferanae continues as the most effective parasite in Montana. This species, with a less numerous associate, Apanteles fumiferanae, parasitizes the tiny overwintering larvae and kills them when they are half grown. Parasitism of overwintering larvae averaged 36 percent during 1957. Data from collections of larger larvae and pupae have not been completely analyzed but indications are that there have been no striking changes in parasitism since last year.

Egg mass surveys were made in four study plots for the first time in 1957. Collections were made well after all eggs had hatched because hatched masses are more easily detected than unhatched ones. The task is time-consuming and difficult, and a routine check revealed that many masses had been overlooked on first examination. Comparison between numbers of eggs on terminal 15-inch twigs and on whole limbs measured in 15-inch equivalents revealed about three times as many egg masses per unit on an entire limb basis.

The data taken in study plots will reveal the trend in biological factors in various areas of the extensive outbreak of budworm and will determine their effectiveness in regulating changes in populations.

Fir Needle Miner

Epidemics of the white fir needle miner, Epinotia meritana Hein., in Bryce Canyon National Park and the adjoining Dixie National Forest in Utah have caused serious defoliation during the past 20 years. As a result,

mortality of limbs, tops, and some entire trees has occurred. The present epidemic started about 1949 and increased in severity until this year. Considerable tree mortality has developed--more in fact than had previously been experienced.

In 1955 studies were started to collect biological information that might aid in developing possible methods of control. These studies indicated that biological control organisms were present during 1955 at an ineffective level of 8 percent. In 1956 the parasitism increased to 36 percent, and in 1957 reached the level of 71 percent; certain limited areas showed 96 percent. The parasites appeared to be significant factors in reducing the populations to endemic level.

Previous tests of DDT to control the white fir needle miner were not successful; so an experimental aerial spray test using malathion in oil was undertaken against the larval stages. Mortality averaged 75 percent, but it is believed that earlier application of spray would have given better results.

With the reduction in populations during 1957 it is believed that the present outbreak has run its course. The limited research has accumulated facts on life history, seasonal history, and parasites that will be valuable in studies of any future outbreaks.

Tree Class Based Upon Susceptibility to Pine Beetles

A study is under way in Montana and northern Idaho to test the validity of the risk rating of ponderosa pine on susceptibility to attacks by western pine beetle, Dendroctonus brevicornis, and other pine beetles. This risk-rating system, developed in California, is based on current tree vigor as judged by visual crown characteristics; trees having poor vigor are more susceptible to attack than stronger trees.

In Montana this process of risk rating is made difficult because the mountain pine beetle is also a primary pest of mature ponderosa pine. Preference of this beetle for high-risk trees over others is open to question. In order to determine the attack patterns in the same trees by different scolytid species, particularly western pine beetle and mountain pine beetle, data have been gathered from different areas.

The infestation patterns on the boles of 29 ponderosa pine trees infested and felled in 1951, 53 trees in 1954, and 84 trees in 1956 were analyzed during 1957. Interesting data were developed. The trees were scattered in typical mature ponderosa pine stands at locations reaching from western Montana eastward across the Continental Divide into southeastern Montana and northwestern South Dakota. Trees east of the divide were the characteristic 2-needle Rocky Mountain form of ponderosa pine (var. scopulorum).

The infestation patterns confirmed meager earlier pattern analyses showing that the primary attacks were made by the western pine beetle in the westernmost stands in Montana. Progressively eastward toward the Continental Divide, attacks by this beetle became less dominant. They were replaced almost entirely along the western slopes of the divide by the tree-killing attacks of the mountain pine beetle. Since no attacks of the western pine beetle were found east of the divide, we believe that the western pine beetle is not a pest of the scopulorum variety of ponderosa. Here, instead, the attacks were made by the mountain pine beetle or the Black Hills beetle, D. ponderosae Hopk. These two beetle are indistinguishable, either morphologically or by the type of egg and larval gallery design; consequently many insect taxonomists believe that the two species are identical.

The 84 trees felled in 1956 showed considerable variation in infestation pattern in the four geographic areas sampled.^{6/} The schematic presentation in figure 2 indicates the following:

1. The predominance of western pine beetle attacks in Area 1.
2. The predominance of mountain pine beetle and/or Black Hills beetle attacks in the remaining areas.
3. The apparent wide distribution and comparative abundance of ips engraver beetles.
4. The comparative average size of ponderosa pine trees on each side of the Continental Divide.
5. The consistency (91 percent) of basal bole examinations to identify correctly the beetle species responsible for the death of the tree.

Many of the field data and the analyses of them used in this study during 1957 were gathered and studied cooperatively with the Montana State University School of Forestry. The data were used as part of a thesis submitted by a graduate student in partial fulfillment of requirements for the degree of Master of Science in Forestry granted in June 1957.

^{6/} Area 1, westernmost part of Montana, west of the Whitefish, Hungry Horse, Mission, and Sapphire Ranges; Area II, between these ranges and the Continental Divide; Area III east of the divide and north of the Yellowstone River in Montana; and Area IV, south and east of the Yellowstone River in southeastern Montana and northwestern South Dakota.

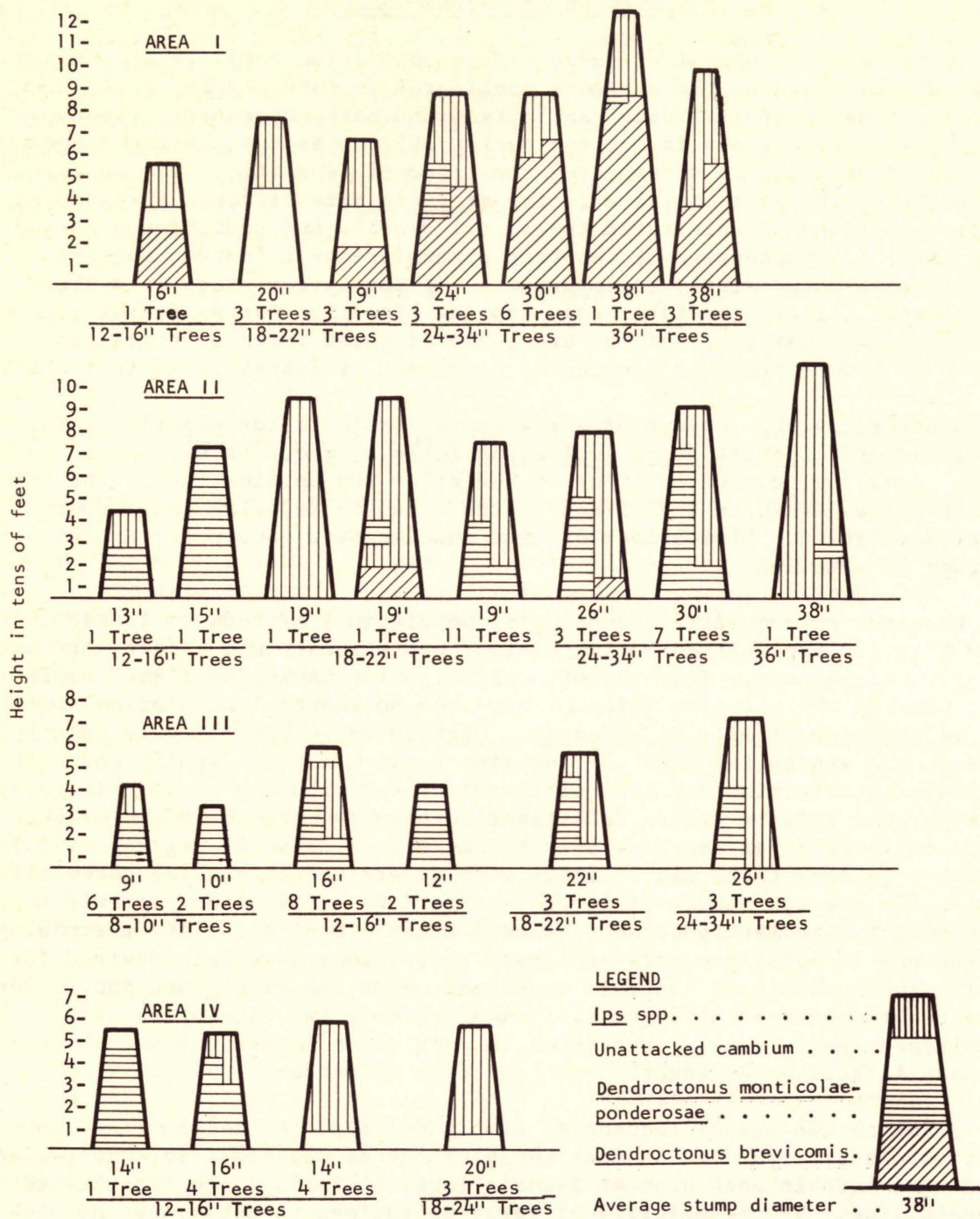


Figure 2.--Bole infestation patterns of scolytid beetles on trees sampled in study areas I to IV in the year 1956

Improvement of Survey Methods

Improvement of appraisal surveys is a continuing need. Attempts are being made to describe the elements considered in interpreting field observations so that appraisal data can be recorded more accurately. Tests were made in two infestations in Montana during 1957 to assess the importance of four characteristics in determining the trend of populations of mountain pine beetle. The four characteristics are: (1) size of trees infested in relation to sizes of uninfested trees; (2) density and condition of brood under bark; (3) percentage of the tree circumference infested, and (4) whether trees occur singly or in groups. If the larger trees in a stand are infested, if they contain heavy healthy brood for the entire or greater part of the circumference of the tree, and if these infested trees occur in groups, an upward trend or continuing high level infestation is indicated.

Determining the success of aerial spray projects for control of the spruce budworm, Choristoneura fumiferana (Clem.), requires extensive sampling. Sampling, conducted prior to and after the application of the spray, is designed to evaluate the effect of the spray in reducing the budworm larval population. Limitations of time and manpower govern the extent of coverage in sampling.

Research on sequential sampling of populations of budworm larvae indicated that its application during control operations would effect more satisfactory measurements. The sequential plan, while having no fixed sample size, permits the classification of pre- and postcontrol populations within the predetermined limits of accuracy. Certain basic knowledge is required to develop a sequential plan for sampling budworm larval populations. It is necessary to determine the type of frequency distribution since this governs which formula will be used. Sufficient information must be known of the number of insects per sampling unit to set class limits or degrees of infestations. In this test, class limits were determined by general correlation between the average number of larvae and percent defoliation per twig as found during a budworm population-damage study. Ordinarily in determining the success of spray projects arbitrary definitions have been devised for setting four classes of control: excellent, good, marginal, and poor. For purposes of this test of sequential sampling only two categories were established: satisfactory--reduction in population 95 percent and above; and unsatisfactory--a reduction of less than 95 percent.

Prior to the use of sequential sampling, fixed collection lines and plots were established in as many spray blocks as was possible, and collections were made in each plot at 5-chain intervals along each established 50-chain line. In the majority of spray operations to date only one such mortality line could be run in a particular spray block of 3,000 to 8,000 acres. Consequently the mortality estimate obtained has been based entirely on one figure not based on a predetermined confidence level.

In contrast, by use of sequential graphs for precontrol and postcontrol sampling of larval populations it is possible to increase the percent of spray blocks sampled with little or no increase in numbers of personnel. For example, assuming that collections at three or four of the plots on a line determine the class of infestation during precontrol sampling or the degree of reduction in postcontrol sampling, the operator can offset repeating his procedure on a new line or can increase the number of blocks in which samples are taken. Whether the increase in samples is placed within a single spray block or more spray blocks is governed by the natural variation found within or between blocks.

The following table presents the situation graphically. From 1955 through 1956 the old system was followed, but in 1957 the sequential plan was followed.

Table 5.--Personnel, acreage, and percent sampling in control projects in southern Idaho, 1955-57

Year	Ground personnel	Acreage sprayed	Acres per person	Number mortality lines established	Lines per person	Percent of sprayed blocks sampled
1955	33	893,214	27,067	58	1.45	53
1956	35	475,901	13,597	70	2.00	68
1957	26	660,632	25,409	107	4.12	83

Actually, only a postcontrol sampling will be needed when research into population-damage relationships enables us to interpret the importance of residual populations.

Results of this work are being reviewed for publication.

INSECT SURVEYS

The annual insect detection and appraisal survey program in the Intermountain station territory covered the most important forested areas. The area of 36.9 million acres of commercial forests with additional noncommercial lands of recreational value requires considerable cooperative assistance from other Federal, State, and private land managers in order to accomplish the level of coverage attained. Station entomologists collected and coordinated forest insect information within the area.

Generally speaking, insect outbreaks remain at a fairly high level in the Intermountain and northern Rocky Mountain States. The spruce budworm was again the outstanding forest pest in Montana and Idaho. Larch defoliators in Montana and northern Idaho have been causing considerable defoliation

in western larch stands. Bark beetles are still causing excessive losses in several areas--the Engelmann spruce beetle in Montana and Wyoming, and the Black Hills beetle in Utah. The mountain pine beetle shows distinct tendencies toward increasing populations in parts of Utah, southern Idaho, western Wyoming, and western Nevada. The Douglas-fir beetle is at a relatively low level in most areas but one heavy outbreak has been recorded in southern Utah. Two situations were revealed that are reported in more detail.

The larch casebearer, Coleophora laricella Hbn., was found in western larch forests for the first time in 1957. This European species was first found in the eastern United States in 1886. While it has been known throughout the northeastern United States and Canada and into the Lake States, its presence in western areas has just been recorded.

Approximately 15,000 acres of young western larch were found to be quite heavily infested in the vicinity of St. Maries, Idaho, some 1,700 miles distant from the known infestations in Minnesota. The presence of a new insect of European origin on an area poses questions of means of introduction, what its potential might be on a new host, what natural enemies might be present in the area, and what can be expected of it in the western areas. Only research can furnish the answers.

For the first time since aerial spraying of budworm was undertaken in this country in 1948 and after approximately 8 million forested acres had been sprayed, extensive infestations of spruce mite, Oligonychus ununguis (Jacobi), were found in fir stands of Montana and southern Idaho. The infestations were located in areas that had been sprayed aerially with DDT to control the spruce budworm during 1956, but lesser infestations in southern Idaho also appeared in one area sprayed in 1955.

It is believed that weather during 1956 and 1957 was abnormally favorable for the development of mite populations. Reviews of survey literature reveals that excessive populations of mites were recorded in 1957 over wide areas in the United States on many agricultural crops. This tendency toward increasing populations coupled with the spraying of large areas at the time is believed to have resulted in the extreme conditions that were encountered.

Abnormally heavy mite populations usually subside to more endemic levels in a relatively short time, and fluctuation in populations seems to be associated with weather conditions during the spring months. Abnormally high temperatures coupled with below-normal moisture favor increases.

Assessment of damage resulting from defoliation by the mites remains to be determined. Plans have also been formulated to determine trends of the present outbreak.

Station entomologists have responsibility for furnishing technical assistance in control projects undertaken by land-managing agencies. During 1957 the entomologists participated in precontrol planning; gave advice on methods, materials, and timing of operations; prepared guidelines, assisted in training project personnel; inspected projects as they progressed; and checked results. A total of 10 control projects required technical assistance during the year, involving spruce budworm, fir needle miner, Engelmann spruce beetle, Black Hills beetle, and southwestern pine beetle.

FOREST FIRE RESEARCH

More than 100 million acres of forest and watershed lands in the Intermountain West require protection from fire. Progress in protecting these resources depends heavily upon results of research. During 1957 research progress was made on several major fire problems--lightning fires, fire-danger rating, fire equipment, fire hazard reduction, and fire behavior.

PROJECT SKYFIRE

Project Skyfire is aimed at the critical lightning fire problem in western forests. The principal objectives are: (1) to gain basic information on the occurrence, behavior, and control of lightning fires and on the characteristics of storms that produce these fires; and (2) to develop methods for suppression of lightning fires including study of cloud modification as a possible means of preventing or reducing severity of lightning fires.

Experiments in cloud seeding were emphasized this year. These experiments were performed with assistance of the Munitalp Foundation, Inc., the President's Advisory Committee on Weather Control, U. S. Weather Bureau, Montana State University, Meteorology Research, Inc., California State Division of Forestry, California Forest and Range Experiment Station, National Park Service, and National Forest Administration.

Cloud-Seeding Experiments

Project Skyfire experiments in 1957 concentrated on observation and analysis of effects produced by ground-based, cloud-seeding generators. Targets for these generators were growing cumulus clouds that may be forerunners of lightning storms. Experiments were intended especially to produce large-scale seeding effects within a test area approximately 30 miles long by 15 miles wide.

This test area was located southwest of Missoula, Montana, on the Lolo National Forest (fig. 3). A network of cloud-seeding generators was located near Lolo Pass in the Bitterroot Mountains on the Montana-Idaho border. This network of generators and the associated test area lie near the center of the Skyfire cloud and lightning survey network. Observations and measurements of cloud-seeding results were obtained by a mobile radar unit at West Fork Butte Lookout and by special weather stations. Aircraft flights in the test area and adjacent check areas provided additional information on clouds, temperature, air moisture, nuclei, and other factors. Weather analyses and special forecasting services were provided by the U. S. Weather Bureau Fire-Weather Forecast Center at Missoula. All these stations and the project aircraft were connected by a special radio network.

During the experiments the cloud-seeding generators were operated on 29 days. A summary of these operations follows:

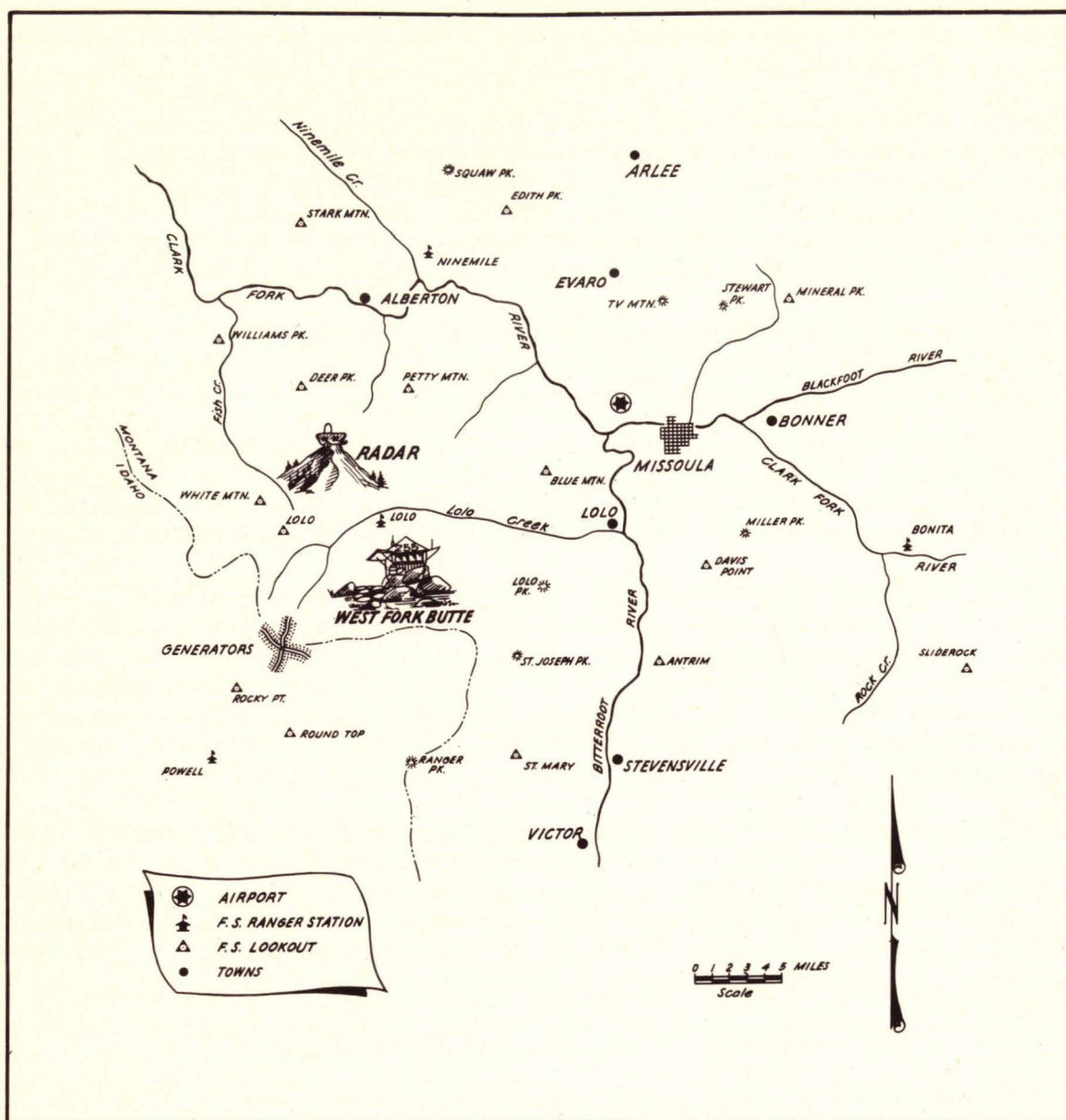


Figure 3.--Project Skyfire cloud-seeding test area on the Lolo National Forest, near Missoula, Montana.

On 24 of the 29 tests some degree of cloud modification was observed. One of the principal measures of modification is occurrence of glaciation or conversion of supercooled water droplets to ice crystals in the clouds in the silver iodide plume produced by generators. With two exceptions, glaciation

was observed wherever cloud temperatures were -4° C. or colder. The two exceptions occurred on July 9, when only one generator was operated, and on August 27, when low-hanging clouds prevented either ground or aircraft observations in the seeded area.

On 10 days during the test period extensive glaciation of the seeded clouds was observed. On each of these days cloud temperatures were -7° C. or colder. However, as shown in table 6, temperatures of -7° C. or colder do not mean that extensive glaciation always occurs. Other factors, such as moisture content and wind effects on cloud development and the silver iodide plume, influence the extent of glaciation and hence the degree of cloud modification.

Glaciation was not observed when measured temperatures were warmer than -4° C. (table 6). No glaciation occurred on July 11 and 23 and August 5, when temperatures ranged from $+6^{\circ}$ C. at cloud base to -1° C. at cloud top.

Silver iodide caused extensive glaciation in growing cumulus clouds as far as 35 miles from the generator site. Glaciation resulting from cloud seeding was photographed extending more than 60 miles from the generator site. This was the extreme limit of the observing network on that occasion.

One conclusion from Project Skyfire operations is that glaciation of both small and towering cumulus clouds invariably results from silver iodide crystal seeding whenever clouds are colder than -4° C. and whenever the silver iodide crystals are carried into the cloud. Therefore, when glaciation is observed as unique to the small test area and does not appear elsewhere in the observational network, this glaciation indicates the degree of seeding in a cloud system.

During these experiments, modification occurred in small cumulus, towering cumulus, and cloud streets 10 to 25 miles in length. Each of these cloud situations exhibited special characteristics when seeded with silver iodide. Analysis of these cloud-seeding effects has been prepared for the President's Advisory Committee on Weather Control. A report on the project's cloud-seeding results will be released early in 1958.

Cloud-Seeding Generator Development

An essential prerequisite for cloud-seeding experiments and for possible future use in lightning suppression operations is the development of a satisfactory cloud-seeding generator. A ground-based generator suitable for these purposes should have the following characteristics: ability to produce a relatively high output of silver iodide nuclei; economical and simple operation; ability to be transported and serviced easily in rough mountainous country; and be safe for use in highly flammable forests.

Several types of cloud-seeding generators were tested and calibrated. None of the generators tested were found entirely suitable. As a result, Project Skyfire carried on a program of research and development aimed at producing the required type of cloud-seeding equipment. During 1957 the

Table 6.--Summary of Project Skyfire 1957 seeding operations

Date	Generators		Freezing level	C l o u d d a t a				Glaciation in clouds in plume area
	Number	Total hours		B a s e		T o p ^{1/}		
				Height ^{2/} feet	Temper- ature°C.	Height ^{2/}	Temper- ature°C.	
July								
8	6	19	12,000	E11,000	+2°	14,000	-4°	Fair
9	1	4	12,000	E12,000	0°	--	--	None
11	29	178	13,000	11,000	+6°	--	--	None
12	8	53	13,000	15,700	-6°	E25,000	E-25°	Good
15	9	27	11,000	10,000	+3°	13,000	-6°	Fair
16	13	84	11,000	11,700	-2°	19,000	E-20°	Good
17	30	186	9,000	10,000	-2°	13,000	-8°	Good
19	29	250	12,500	10,000	+5°	15,300	-4°	Fair
22	22	134	12,500	12,500	0°	--	--	Fair
23	26	150	12,500	9,400	+4°	12,000	+1°	None
25	11	27	13,500	14,500	-2°	E32,000	E-40°	Fair
26	14	114	12,500	11,500	+1°	--	--	Fair
29	30	156	13,000	11,500	+4.5°	E25,000	E-27°	Good
30	16	54	12,500	13,000	-1°	16,500	-7.5°	Fair
August								
5	7	15	13,000	11,300	+4°	13,500	-1°	None
6	10	44	10,000	9,000	+2°	14,000	-8°	Good
7	8	23	10,000	10,000	0°	15,000	-9.5°	Good
8	16	56	12,000	12,000	0°	14,500	-4°	Fair
9	16	56	12,600	15,000	-7°	E18,000	E-12°	Fair
14	15	98	11,000	13,800	-8°	E16,500	E-13°	Fair
15	13	91	11,700	13,500	-4°	E17,000	E-11°	Fair
16	4	32	12,000	13,600	-3.5°	17,000	-9°	Good
19	27	104	12,200	12,200	0°	20,500	-17°	Good
20	6	36	12,000	15,000	-8°	17,000	E-12°	Fair
21	15	42	11,900	12,900	-3°	E14,900	E-7°	Good
22	30	276	10,500	11,600	-2°	E25,000	E-25°	Good
23	15	81	11,900	14,000	-6°	E20,000	E-17°	Fair
27	15	86	7,800	8,300	0°	--	--	Obscured
28	15	84	9,000	10,000	-2°	E20,000	E-20°	Fair

^{1/} E indicates estimated.^{2/} Mean sea level.

project designed and tested a highly satisfactory cloud-seeding generator. Forty of these generators were manufactured and used during the 1957 Project Skyfire experiments. The same design was used for generators operated on lightning fire experiments in California.

The Project Skyfire cloud-seeding generator shown below is a silver iodide-acetone solution burning unit with an external mixing injection system. The acetone solution is drawn from a reservoir through a modified hypodermic needle and nebulized by a jet of propane gas. The mixture of atomized acetone solution, propane, and air is directed into a flame chamber and ignited. The volatilized silver iodide condenses into crystals as the smoke passes from the flame and around a quench plate mounted above the flame chamber. The silver iodide smoke is carried away from the generator by convective currents and the surface wind. Output of this generator is $3 \text{ to } 4 \times 10^{13}$ nuclei per second effective at -20° C . when consuming 600 milliliters of 4-percent silver iodide-acetone solution and 1 pound of propane per hour at sea level pressure.

Studies of Nuclei

Cloud-seeding research involving use of silver iodide generators requires measurement of the area covered by the generators and the life and concentration of the nuclei. The project has developed techniques for these measurements and for evaluation of the results. The system involves measurement of local winds and convective activity, use of aircraft to take air samples in the silver iodide plume area, and employment of portable cold boxes in aircraft and on the ground to detect presence and concentration of both silver iodide and natural nuclei.



Project Skyfire silver iodide cloud-seeding generator being serviced in the field.

During this year's experiments 31 silver iodide plume-tracing flights were made by project aircraft shown below. These flights plus other observations of weather conditions provided data for preparing maps of the silver iodide plume area for each cloud-seeding operation. These maps greatly help in evaluating cloud-seeding results.

One major finding shows that silver iodide nuclei in the test area had a relatively low rate of deactivation. This factor is important if ground-based generators are to be used successfully in cloud-seeding operations. This year's experiments show that deactivation of silver iodide in the free atmosphere exposed to sunlight for periods longer than 30 minutes was less than one order of magnitude per hour.

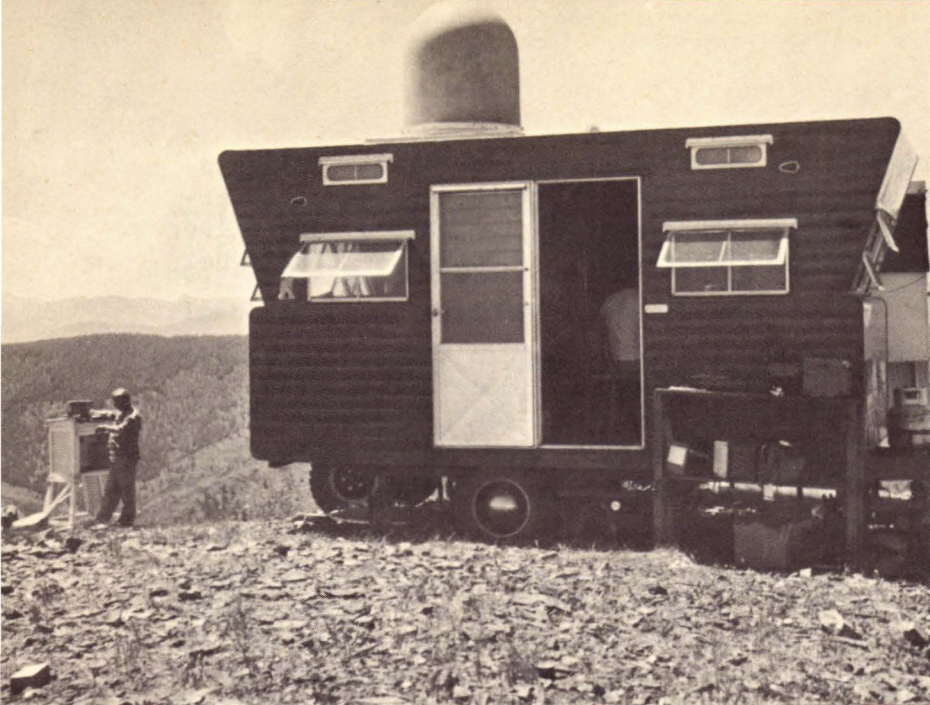
The project's nuclei studies have shown that silver iodide may be used as an air tracer for many other types of research. These techniques are being used in local wind surveys important in studies of the spread of blister rust, and have wide application in micrometeorology and fire behavior research.

Radar

The mobile radar unit, developed by Project Skyfire in 1956 and used throughout the 1957 fire season in lightning fire research, was placed on a high peak in Lolo National Forest cloud-seeding test area. Returns on the radar scope showed the development of strong precipitation cells and locations and movements of lightning storms. Time lapse motion pictures of the radar scope provided a permanent record of storm systems moving across the test area and surrounding country.

Observer ready for takeoff on nuclei-tracing flight. Cold box in foreground will be mounted in right front seat of aircraft. Air samples placed in cold box during flight determine location and concentration of silver iodide nuclei in cloud-seeding test area.





Project Skyfire mobile radar unit is surplus military gear, modified for special lightning research and mounted in a 14-foot trailer. This unit detected and tracked lightning storms in cloud-seeding test area and surrounding territory.

The usefulness of radar in detection, tracking, and analysis of lightning storms has been demonstrated. Other uses, in forest-fire control, are being developed. The Sky-

fire radar was used once this season to predict severe winds accompanying a lightning storm moving near a going fire. Warnings of this storm movement relayed directly to the fire boss permitted the suppression crew to attack the fire more safely and effectively. Radar tracking and analysis of this storm also provided information on the location of shower zone near the fire.

As a special project, Dr. Tetsuya Fujita of the University of Chicago, Department of Meteorology, under auspices of the Munitalp Foundation, studied lightning storms with the Skyfire radar. He studied individual storm cells in relation to topographic factors as shown by ground clutter on the radar scope. The ability of radar to show topographic features also may have future value in seen area mapping for fire detection.

Cloud and Lightning Survey

For its fifth consecutive season, the network of 22 Skyfire lookout stations provided detailed information on cumulus cloud characteristics, thunderstorms, lightning, and lightning-caused fires. The network reported these conditions daily by radio to Skyfire headquarters in Missoula where cloud and lightning maps were plotted currently. These maps provided material for making useful comparisons between the cloud-seeding test area and the surrounding lookout network.

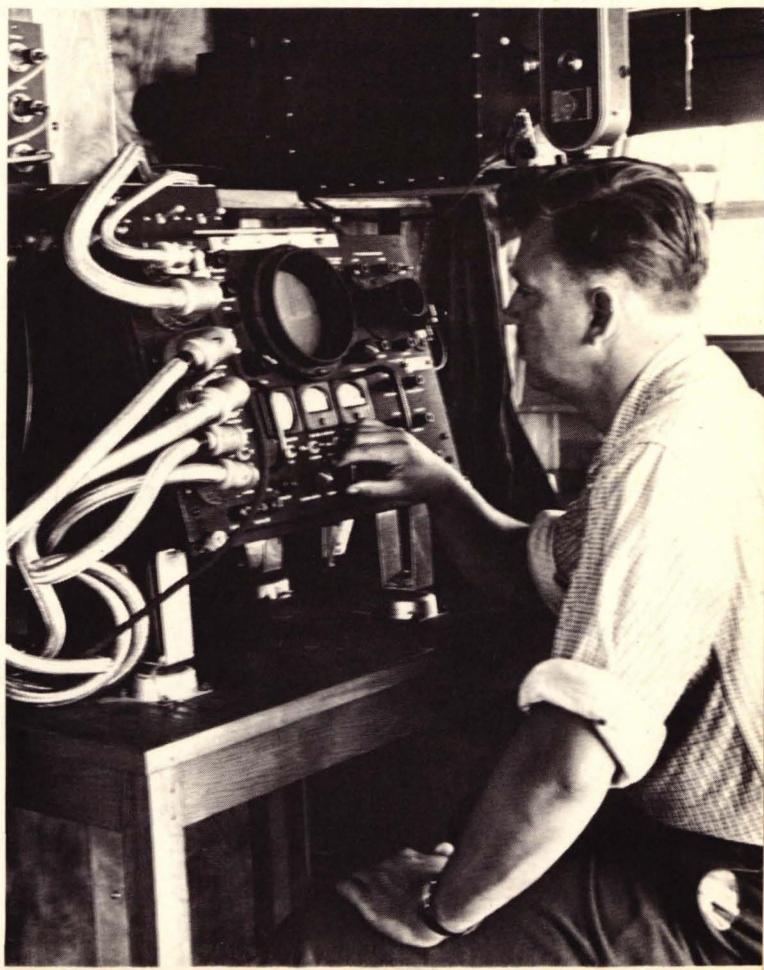
Lookout firemen at each station received 3 days of intensive instruction in cloud identification, measuring, and reporting procedures. The network functioned smoothly and provided additional information on cumulus clouds and lightning throughout the Intermountain West.

Techniques for cloud and lightning surveys have been developed and tested so as to have wide application in fire control throughout the western United States. During 1958 a lookout cloud and lightning observation handbook will be prepared. It will be a guide for fire control personnel who observe clouds and lightning for use in fire-weather forecasting and planning of fire suppression operations.

Summary of Project Skyfire Results

The principal results of Project Skyfire to date are: (1) development of basic knowledge on lightning storms and lightning fires; (2) creation and testing of a system for cloud and lightning surveys; (3) development of equipment including cloud-seeding generators and radar; (4) development of special techniques for cloud-seeding and physical analysis of results; and (5) conduct of experiments which show that growing cumulus clouds can be modified. The next major step in this research program is to determine whether the techniques and equipment used in modifying cumulus clouds can change their electrical characteristics. Experiments aimed at this objective are now being designed.

Scope of Project Skyfire mobile radar unit is monitored to obtain cloud and lightning storm information during field experiments. Time lapse camera in upper right records action from a second scope.



FIRE BEHAVIOR

Atmospheric Studies

During 1957 exploratory studies were made of fire behavior in relation to the jet stream and other atmospheric factors. Preliminary results have already been reported.^{7/}

These preliminary studies involved analysis of 23 high-intensity fires occurring in 1955 and 1956, all of which exhibited unusually severe or blowup fire behavior. These fires were analyzed in relation to large-scale atmospheric patterns. Studies were made of gusty ground winds and formation of Bernard cells in relation to the jet stream; characteristics of high intensity fires under jet stream influences; and variations in atmospheric electricity and condensation nuclei in the fire areas. These studies show need for a better understanding of large-scale atmospheric factors in relation to surface conditions associated with critical fire behavior.

Fire Behavior Training

A servicewide fire behavior training school will be held at Missoula in the spring of 1958. This school will present major findings of research in fire behavior. The program includes basic meteorology, fire physics, fire behavior, fire problem solutions, and methods for training of field personnel. The staff, under direction of the Washington office, includes members of fire research staffs at forest experiment stations, regional fire control personnel, and meteorologists of the Munitalp Foundation, U. S. Weather Bureau, and Yale University. Intermountain station's Division of Forest Fire Research will develop a special training course and training equipment in fire behavior for this school.

FIRE-DANGER RATING

Fire-Danger-Rating System

The year 1957 marked the third season of use of the Model-8 burning index meter in forest protection areas of the Intermountain West. Assistance was continued to various private, State, and Federal agencies in planning location of fire-weather stations, inspection of stations, training of personnel, and interpretation of fire-danger-rating information in the planning and managing control operations. In cooperation with the U. S. Weather Bureau, the development of fire-weather operations that aid both fire-weather forecasting and fire-danger-rating activities was continued.

^{7/} Schaefer, Vincent J. 1957. The relationship of jet streams to forest wildfires. Jour. Forestry 55(6): 419.

Cooperation with Bureau of Land Management

Fire-danger-rating studies were continued in cooperation with the Bureau of Land Management in Alaska. The 1957 fire season was the most severe in the forests of interior Alaska since organized protection began in 1940. More than 5,000,000 acres were burned; the main damage was caused by a series of lightning fires that destroyed forest and wildlife resources and created a giant pall of smoke that seriously restricted aircraft operations. At the peak of the Alaska fire season, Charles E. Hardy, Division of Forest Fire Research, visited the Alaska fire areas to evaluate fire-weather factors, observe actual burning conditions, and make on-the-ground analysis of the experimental use of the Intermountain fire-danger-rating system.

The unusual fuels in interior Alaska are important in fire-danger rating. Vast areas have very fine fuels such as reindeer moss intermingled with the forest cover. At a critical point, fire flashes through these fuels and then ignites and spreads rapidly in heavier fuels. An important phase in fire-danger-rating research in Alaska is to determine how to interpret fire-weather factors and burning index ratings to indicate fire intensity and spread in these fuels. Fire-danger-rating factors also require study in relation to application in lightning storms, the planning of fire detection, prevention of man-caused fires, and the buildup of critical fire weather in the spring and early summer. Alaska is truly a pioneer area for forest fire research.

Fire-danger rating has major importance to the Bureau of Land Management in the West. This bureau needs methods especially for application of fire-danger-rating information in fire control on western range areas. To accelerate fire-danger rating in these areas a broad cooperative program has been agreed upon by the Bureau of Land Management and the Forest Service. The Bureau of Land Management will station a liaison officer with the Division of Forest Fire Research at Missoula. Together they will develop fire-weather measurement systems and application of fire-danger-rating methods for the western protection areas of the Bureau of Land Management.

Fuel Moisture Studies

Fuel moisture is a major factor in fire-danger rating. Gaining a better understanding of how to measure fuel moisture and how to interpret these measurements in relation to other fuel and weather factors has long been an important objective of research. The Intermountain station's study of fuel moisture includes development of techniques and equipment for measurement studies of moisture changes in various fuels, and analysis of fuel moisture factors in relation to fire season severity and buildup of conditions conducive to high-intensity fires.

Work is continuing on the maintenance of high quality in the manufacture of fuel moisture sticks and in the development of improved fuel moisture measuring systems. The one-half inch sticks manufactured at the Forest Service Spokane warehouse and used by nearly all forest protection agencies in

the West are tested for quality control during each fire season at the Priest River Experimental Forest. Weathering tests were made in 1957 in three different climates at Cascade Head Experimental Forest in western Oregon, Priest River in northern Idaho, and the Desert Experimental Range in western Utah. Three density groups of fuel moisture sticks were exposed at these locations, both under protective screens and in full sunlight. Results of this study may show how to manufacture sticks that weather less during a fire season and also how to expose these sticks to maintain greatest uniformity.

Western-type one-half inch fuel moisture sticks and eastern-type bass-wood slats are being studied under varied weather conditions. These studies were carried on in 1957 in cooperation with the Bureau of Land Management in Alaska and southern Idaho, the National Park Service in Utah, and by the Forest Service in northern Idaho. Results of this study may help develop better fire-danger-rating methods for fine fuels such as the grass and sagebrush stands of the Intermountain West and the tundra, reindeer moss, and muskeg areas of interior Alaska.

Studies of moisture variations of large logs in relation to fuel moisture as measured by sticks and slats and seasonlong variations in basic weather factors are being continued. Results of these studies already have contributed basic information about fuel moisture for the development of several fire-danger-rating systems used in the West. Because this study may indicate methods for predicting the buildup of a critical fire season, measurement of fuel moisture in large logs will continue at the Priest River Experimental Forest. To provide this type of data for a drier climate, a similar experiment was installed in the fall of 1957 at the Boise Basin Experimental Forest.

FIRE EQUIPMENT RESEARCH

The forest fire research program requires consideration of equipment needs and techniques of employment as well as development of special items of equipment for use in research. In addition, the Intermountain station is carrying on special fire equipment development projects aimed at designing, adapting, and testing specific items for general use in fire control.

Portable Fire-Weather Station

A portable fire-weather station has been designed and tested for use at the scene of going fires, prescribed burning operations, slash disposal work, and other forestry activities where on-the-site measurement of weather factors is needed. Packaged in a compact aluminum shelter, the 35-pound weather station contains instruments for measuring wind velocity, relative humidity, maximum and minimum temperatures, precipitation, and fuel moisture. During recent tests, this portable weather station was dropped successfully by parachute from an airplane. Final tests are now under way on 22 proto-type units already sent to various regions in the United States and Alaska for field evaluation. Preliminary manufacturing specifications are being prepared with assistance of the Forest Service, Arcadia, California Equipment Development Center.

Portable weather station set up in the field.



Fire-Weather Instruments

Research and development work on several new or improved fire-weather instruments is nearing completion. An electric fan psychrometer kit and an electric totalizing wind counter are ready for commercial manufacture. Preliminary tests have been completed on an aluminum rain gage. A small weather kit, carried in a canvas bag fastened to the belt of a forest officer, is ready for field testing. This "ranger's weather kit" contains a sling psychrometer, venturi tube-type wind meter, psychrometric slide rule, plastic water bottle, miscellaneous weather forms, and burning index meter.

Recording Fire-Weather Stations

Two types of automatic recording fire-weather stations are in the preliminary development stage. One type records readings of wet and dry bulb temperatures, wind velocity, time, and fuel moisture by a photographic process. The first photographs have been obtained from the battery-powered experimental model designed to record measurements at forest stations that cannot be manned at the time set for fire-weather observations. The second unit, now ready for initial assembly, is a continuous recording fire-weather station. Designed for use at key fire-weather stations and on special projects requiring continuous weather data, this battery-powered equipment records wet and dry bulb temperatures, wind velocity, and fuel moisture once each hour.

Knock-down Aluminum Instrument Shelter

At regular fire-weather stations meteorological instruments must be sheltered and exposed in a standard manner so as to give accurate and uniformly consistent readings. Furthermore, at many stations such as fire lookouts, the shelter and the instruments must be dismantled during the winter months to prevent damage by severe weather. To meet these requirements, a new type knock-down weather instrument shelter has been designed; pilot models have been built and tested. Aluminum was selected as the basic material in an attempt to save weight, promote ease of assembly and disassembly, and take advantage of possible savings through use of metal stampings. Tests made by the Instrument Division of the U. S. Weather Bureau show that this new instrument shelter varies less than one degree from temperature readings made in a standard Weather Bureau cotton region-type instrument shelter.

Controlled Temperature-Humidity Cabinet

This year the Division of Forest Fire Research completed design and construction of a controlled temperature-humidity cabinet. This equipment will be employed in analyses of moisture content of forest fuels, testing of relative humidity measuring devices, measurement of changes in fuel moisture sticks, and calibration of instruments used in fire-weather operations. This equipment is a forerunner of a larger, more fully controlled unit planned for inclusion in a proposed forest fire laboratory.

Advanced Equipment Research

Several possibilities for development of new types of fire equipment were studied by the Division of Forest Fire Research this year. These possibilities include: (1) an electronic instrument to count and locate lightning strokes for use at fire lookout stations; (2) adaptation of radar for seen area mapping in fire detection studies and use in mobile weather units for predicting thunderstorm induced winds and precipitation areas; and (3) modification of surplus military range finders for use in cloud measurements and observation of forest fire smoke columns. Also, studies on the development of research facilities and equipment for a proposed forest fire laboratory were continued.

LOGGING SLASH RESEARCH

During 1957 flammability tests of 5-year-old chipped logging slash were completed at the Priest River Experimental Forest. Burning this slash showed that all species and all quantities had very low flammability. Chipping causes an immediate and large reduction in flammability; therefore the 5-year-old plots showed no great change from the results obtained in burning fresher chipped slash.

A logging slash review was held in the fall of 1957. Personnel from Forest Service Regions 1, 2, and 4 and the Rocky Mountain Experiment Station observed logging slash operations at the Priest River Experimental Forest and on the Kaniksu, Kootenai, Deerlodge, and Lewis and Clark National Forests. Special attention was given to results of logging slash research and methods of slash treatment in the Engelmann spruce and lodgepole pine types.

Analysis of slash measurement methods was continued. Results show that quantity of slash from cutting a given stand can be estimated with acceptable accuracy from measurements of standing trees. Crown weight is proportional to the product of d.b.h. and crown length. Tables of crown weight by d.b.h. classes have been prepared using average crown length values. Although subject to considerable error if used to estimate the crown weight of an individual tree, these tables can be used in conjunction with stand tables to obtain satisfactory estimates of slash weight per acre. Greater accuracy can be attained by measuring representative crown lengths in each stand to be estimated. Weight of slash per M bd. ft. cut varies widely with species and size of material.

Studies of fire spread in slash were continued. Results of experimental burning indicate that rising relative humidity proportionately reduces rate of fire spread. While the actual reduction is greatest in light concentrations of fuel, percentage reduction is approximately the same for all weights per acre. During the year of cutting, quantity of slash is the main factor affecting rate of spread, although lesser effects of species characteristics are noticeable. Thereafter species becomes more important because of differences in rate of decomposition.

Fire intensity, measured in terms of heat radiation, closely parallels rate of spread. Because of the large quantity of attached foliage, raised from the ground and well-aerated, fires are especially hot in heavy concentrations of fresh and 1-year-old western white pine and lodgepole pine slash and fresh Douglas-fir and grand fir slash. When a large area of slash is burning rapidly, flames reach high into the air and often pulsate rhythmically. Ignition of gases in the convection column above the main body of flames occurs commonly. The maximum emissivity of slash fires approximates 0.30.

FOREST ECONOMICS RESEARCH

FOREST SURVEY

The national Forest Survey program provides for inventory of all commercial forest land in the United States and for periodic reinventories of these lands to keep the resource data current. The Forest Survey Unit of the Intermountain station carries out the survey program in all the Rocky Mountain states from the Canadian border to Mexico and in the Black Hills portion of South Dakota. This territory embraces nearly one-third of the land area of the United States, about 22 percent of the forest area, and 11 percent of the commercial forest area.

The initial survey has been completed in Montana, Idaho, and South Dakota; it covers about one-third of the forest area of the Rocky Mountains. The area including Wyoming, Utah, Nevada, Colorado, Arizona, and New Mexico is the only portion of the United States not yet covered by the Forest Survey. Initial surveys are progressing in Colorado and Wyoming. A reinventory survey has been completed in northern Idaho and is now under way in western Montana.

Initial Survey

For the last 2 years the field program has been concentrated in Colorado and Wyoming. The survey has been closely coordinated with the forest management inventory program of the national forests in Regions 2 and 4. Regional personnel have delineated forest cover on aerial photos, have transferred these delineations to base maps, and have computed area of the various types and stand-size classes. Forest Survey crews have located field plots from points pinpricked on aerial photos and have carefully measured and recorded tree dimensions and conditions. All field data have been assembled and reviewed by the Intermountain survey staff and forwarded to the California IBM Unit^{8/} for machine tabulation.

During the year, twelve 2-man survey crews completed field work on nearly 6 million acres of forest land in Colorado of which approximately 2.6 million acres were commercial forest land. This is about 28 percent of the commercial forest area of the State and brings the completion rate for the 2-year period to 54 percent. Two more field seasons probably will be required to complete the survey in Colorado.

In Wyoming, field work was completed on 722,000 acres of forest land (688,000 acres of commercial forest land) on the Medicine Bow National Forest in cooperation with Region 2; and 607,000 acres of forest land (594,000 acres commercial forest land) on the Teton National Forest in cooperation with

^{8/} Operated by California Forest and Range Experiment Station as a Service Unit for the California, Intermountain, and Alaska Experiment Stations.

Region 4. About half of the commercial forest area in Wyoming has now been covered by the Forest Survey. At the present rate, field work for the entire State will be completed in 2 more years.

An interesting feature of the cooperative field program on the Teton National Forest was use of a helicopter to transport field men to plots in the back country. This program, developed and carried out by Region 4 with Forest Survey assistance, eliminated need for organizing pack trips. Preliminary reports on this program indicate that the cost per plot for transportation by helicopter was about the same as by pack train but that the helicopter saved considerable time; that is, the same number of men completed survey of a given number of plots in less time by helicopter than by pack train. This may mean that mechanization has caught up with timber cruising and that the traditional string of pack animals and riders will disappear from timber surveys of the back country.

Maintenance Survey

Field work on the reinventory of forest resources of western Montana was continued at full scale during the year in close cooperation with the Timber Management division of Region 1. The Bureau of Land Management also assisted by field examining survey plots on BLM land. A total of 2.9 million acres of forest land was covered, of which 2.2 million acres were commercial forest land. The area of commercial forest land in Montana covered by the reinventory is now 7.6 million acres, or nearly one-half of the State total.

Plans for 1958 provide for completing the reinventory in western Montana on both public and private land. Profiting from the helicopter experience gained on the Teton National Forest, preliminary plans have been made for using helicopters to transport survey field men to plots in remote portions of the Flathead National Forest next summer.

Timber Cut

In cooperation with the Bureau of the Census, surveys of lumber production in 1956 were made for Idaho and Montana. Lumber production for the year set new records in both States. Idaho's mills sawed 1.6 billion board feet, while Montana's mills produced 981 million board feet.

In Idaho, Douglas-fir, true firs (mostly grand fir), and ponderosa pine accounted for nearly two-thirds of the total production (see following tabulation). Engelmann spruce was the principal species cut in Montana, chiefly because of intensive efforts to harvest timber killed or infested by the spruce bark beetle.

Lumber production in Montana and Idaho, 1956

<u>Species</u>	<u>Montana</u> <u>Millions of board feet</u>	<u>Idaho</u> <u>Millions of board feet</u>
Douglas-fir	237	399
Engelmann spruce	340	221
True firs	9	305
Ponderosa pine	157	304
Western white pine	39	184
Western larch	147	125
Other	52	71
Total	981	1,609

Concurrently with the lumber production study, surveys of the 1956 output of other primary products were made for determining the total volume of timber cut in Idaho and Montana. Results of the pole production survey have been published, and data for other products--sawlogs, veneer logs and bolts, pulpwood, mine timbers, and miscellaneous products--are being compiled.

The pole production survey, made annually in cooperation with the Rocky Mountain Pole and Treating Association, covers northeast Washington, northern Idaho, and Montana. The 1956 survey showed a total production of 577,650 poles, almost double the 1955 total. Lodgepole pine was the leading pole species in 1956, as shown in the following tabulation:

<u>Species</u>	<u>1955</u> <u>Thousands of pieces</u>	<u>1956</u> <u>Thousands of pieces</u>
Western redcedar	132	194
Lodgepole pine	95	237
Western larch	62	111
Douglas-fir	6	36
Total	295	578

The survey of Montana Christmas tree shipments is also made annually. In 1956, the all-time record of 4.2 million trees was shipped out of Montana by rail and truck. Flathead and Lincoln Counties, the leading producing areas, accounted for nearly two-thirds of the total production.

Aerial Photo Interpretation

Probably the most significant development in aerial photo interpretation research during the year was publication of Preliminary Aerial Volume Tables for Conifer Stands in the Rocky Mountains. The tables, prepared from photo and field measurements of the same plots, enable the estimation of timber volume directly from the photographs. By measurement of tree heights, crown widths, and stand density on the photos and application of the aerial volume tables, a trained interpreter can quickly obtain volume data that are adequate for preliminary appraisals, volume estimates of inaccessible or low value stands, or for estimates of serious disease or insect losses. The tables are designated as preliminary because additional plot data are needed to assure better accuracy. Tests of their accuracy in various parts of the Rocky Mountain area are also needed to aid in determining their applicability. Tests made in cooperation with Forest Inventories Research Section of the Canadian Government at Ottawa indicate that aerial stand volume tables of this kind may also be adapted to Canadian timber stands, particularly for obtaining volume estimates for the large areas of inaccessible timber in the northern portion of the provinces.

Other photo research has included testing the accuracy of making area determinations by dot sampling on photos and preparation of training aids and manuals. A joint publication by this station and the Washington office gives detailed instructions for use of the parallax wedge in photo measurements. During the year Karl Moessner has conducted photo training courses for station and region personnel, industrial foresters, and forest school students.

FOREST ECONOMICS

In recent years the economic studies made by this station have been directed primarily to the problem of describing in broad terms the opportunity for development of the timber industry in this part of the Mountain States and the present and ultimate place of timber in the economy of the region. These states have millions of acres of commercial forests only partly developed. If management is to be properly oriented to produce the greatest long-range benefits, it is important to have a realistic appraisal of the forests' place in the regional economy.

Three reports aimed at this problem were published in 1957. Research Paper 50, Market Prospects for Mountain States Timber, reviewed the national long-range timber growing task with special emphasis on what the national wood production means as timber opportunity in the Rocky Mountain area. The conclusions presented are encouraging. Lodgepole Pine, A Lumber Species analyzed the qualities of this species for lumber as well as some of the problems involved in expanding use of it. Since the 14,000,000 acres of this type in the West have had little logging to date, this paper has special interest and significance. The third paper in this group, Industrial Opportunities in the Headwaters Timber Development Unit, analyzes development problems and opportunities of an individual area. The Headwaters Timber

Development Unit includes southeastern Idaho, western Wyoming, and a bit of northern Utah. Except for the hewed tie operations of the past and the scattered cutting of small sawmills, there has been little use of the timber in this area. This is one of the localities where considerable development will be made in years to come.

Another investigation, currently in process, goes beyond considerations of just the forest resource and evaluates the economic potential of the Mountain States area as indicated by its minerals, farmlands, water, and other physical resources. This study also is attempting to determine whether aridity, or lack of resources, or some other basic factor imposes a low ceiling on the prospects for regional growth, or whether, on the other hand, the region still has considerable opportunity for growth. The over-all economic outlook is an important consideration in forestry and other planning.

A general study of the lumber transportation problem was started in 1957. Railroad waybill statistics compiled by the Interstate Commerce Commission and other data are being studied to determine long-range trends in lumber distribution that affect the marketing of Rocky Mountain lumber. The waybill statistics also contain useful data on rail freight costs. This analysis should bring some of the marketing problems and opportunities into clearer focus.

Work was begun this year on analysis of opportunities for the timber industry in the Clark Fork Timber Development Unit in western Montana. This has long been an important lumber-producing area, but it suffers from the lack of fiber-using industries. Regional Forester Tebbe has requested this study to reevaluate industrial needs and opportunities. Attention will also be given to the matter of forest management needs if industrial objectives are to be realized.

Preliminary steps were taken in 1957 toward building parallel economics research programs in the range and watershed fields. The growing conflict over rangeland use obviously cannot be resolved without looking beyond the land itself to the broader question of how use of the land affects the hopes and aspirations of the region. A much more complete measure of long-time water values is necessary. We need to know how important the wild-land forage is to the agricultural economy and to the total economy. Certainly one reason the range problem has not been met decisively has been that the issues and alternatives have not been clear-cut. It is to be hoped that broad economic studies of range and watershed can provide that clarification.

FOREST UTILIZATION RESEARCH

Forest Utilization Research performs a unique and distinct function in the Intermountain station. This is by far the smallest unit, and it conducts the least amount of direct experimental research; yet it has at its fingertips the largest single research unit of the Forest Service, namely, the Forest Products Research Laboratory at Madison, Wisconsin. No other phase of the research program is so organized. The Forest Utilization Research division acts as the eyes and ears of the Forest Products Laboratory and aims to perform a threefold function:

1. To evaluate needs for research in forest utilization and to see that these needs are met.
2. To put the results of utilization research into early effect.
3. To conduct research for which it is technically equipped or which can be done best in the field.

Behind this entire program lies deep-rooted belief that utilization of products from the forest is the ultimate. Broadly, this philosophy extends to all other branches of forest research. Research in this division is restricted to use of the timber resource; timber growth without timber use would be futile. The intent of this division is to assure increasingly improved use of the timber resource.

Previous years have seen vast increase in the number of wood-using industries throughout Intermountain station's territory. However, business conditions during 1957 forced many companies to delay or curtail planned programs of expansion. A few of the smaller, marginal sawmills have ceased production altogether; many other mills have been forced to restrict their output. Despite this temporary setback, the region has great potential both for growth of established industries and also for development of new industries. The program of utilization research is closely associated with the long-term resource development of the region. During 1957 some progress was made towards accomplishment of this objective.

TIMBER GROWTH AND UTILIZATION RESEARCH

The staff is actively interested in developing sound usable log grades. This is no short-term program but will have to continue over a number of years. The ultimate goal of this program is to develop log grades that will differentiate between the qualities of standing trees. During the year the staff attended several meetings of the regional log grade committee, and represented the station at the National Log Grade Committee meeting at

Quincy, California, and at the Timber Quality Conference at Madison, Wisconsin. This latter meeting stressed the importance of timber quality in the forest survey, forest management, and forest utilization programs, and also emphasized need for more and better log- and tree-grade studies.

Eight lumber-grade studies were started or completed in 1957. Final data were collected for the Douglas-fir study started in 1956. This study was designed to develop criteria for Douglas-fir log grades and to determine the effect of compression wood on lumber grade yield. Trees having varying degrees of lean were selected in the woods; then they were felled, bucked, and milled, and the lumber yield was graded and tallied green, dry, and after 6 months' storage. The Forest Products Laboratory is responsible for the analysis and publication of these data.

One of a series of studies of white pine was made at a sawmill in Superior, Montana. This particular study was designed to determine the effect of sawing method on the quality and quantity of the lumber yield. Trees for this study were selected in the woods and, after felling and bucking, all logs were diagramed. Four different methods were used to saw the logs. The lumber was graded and tallied green, after drying, and after surfacing. Analysis of these data also will be prepared by the Forest Products Laboratory.

Loggers and sawmill managers have shown great interest in the problems of harvesting steep mountain watersheds and lodgepole pine stands. We hope to direct this interest toward organizing a logging committee that will evaluate existing equipment and encourage development of new equipment that will meet the special needs of this mountainous country.

Two experimental studies of the effect of spiral grain on the twisting of poles in service are now nearing completion. The study at Newport, Washington, probably will be completed in 1958, but collection of data at the Libby, Montana installation will continue.

Several projects have been undertaken to help sawmill operators. One has been a series of clinics designed to meet needs of some of the 1,000 small mills in our area. Their chief problem is to make better quality lumber at cheaper cost, to use raw materials more efficiently, and to improve their marketing. The larger mills have problems of a different type. Some companies have broadened their product base to include paper-overlaid lumber, edge-glued lumber, and laminated dimension. Each of these new products brings results of earlier research into commercial use; and by the same token, each new manufacturing venture is accompanied by new needs for research.

One of the major changes in the operation of lumber companies in recent years has been the great increase in storage of logs on dry ground--"cold decks," as they are called in the trade. Reasons for this change are many, and new problems in log deterioration have accompanied the change. A major study conducted by the station this year at Libby, Montana, was designed to

measure deterioration and to provide guidelines for corrective action. Results of this study will be reported separately; but, in brief, they show that logs kept moist by artificial spray neither decay nor check; that application of this spray on log ends is important; and that more power is required to saw dry logs than wet ones.

PULP AND PAPER

Long-term efforts at developing outlets for wood fiber-waste wood have been rewarding. The most prominent advance in fiber utilization has been the completion, late this year, of a new kraft pulp mill near Missoula, Montana, with designed capacity of 250 tons per day. It was built by the Waldorf Paper Products Company and will use chipped residues from numerous mills located within a 100-mile radius; pulp processed here will be shipped to Minnesota for processing. Establishment of this mill should go far towards bettering the wood utilization procedures of chip suppliers. Installation of barkers at numerous mills has provided outlets for sawmill residues previously unusable. The enforced use of barkers will establish their merit and may point the way for their use in other sawmills in the territory. The Waldorf mill has incorporated many important features of advanced engineering design; its nearly complete chemical recovery processes result in tremendous reduction of stream pollution from effluents.

Construction of a paper mill by the St. Regis Paper Company at Libby, Montana, has been delayed, but the company is making additional studies of wood residues with a view to eventual construction. The Boise Cascade Corporation has announced plans for a corrugated container plant at Burley, Idaho.

It is hoped that additional pulp and fiber industries will become established within the station territory, for the supplies of wood and water necessary to support such industries are ample. The division has concentrated effort on finding suitable sites for new pulp mills, has given technical assistance to the lone particle board manufacturer in the region, and has fostered the construction for increased capacity at established pulp mills.

PHYSICS AND ENGINEERING

Reevaluation of basic strength properties of inland Douglas-fir has aroused considerable controversy in the Intermountain region. Significance of this tremendous problem is evident from the increases in Douglas-fir production, and many companies are planning to increase their production still further even though they foresee marketing problems arising from assignment of differential strength values. The lumber industry is alert to problems raised by the Forest Products Laboratory report on Douglas-fir strength, and has promised to cooperate with the laboratory in resolution of these problems. This division continues to work closely with representatives of industry in attempting to establish workable values for Douglas-fir strength ratings.

The recent mill study at Superior, Montana, emphasizes importance of well managed and operated dry kilns. This mill, cutting only white pine, is experiencing difficulty in drying water-core stock. Mixing this material with normal run lumber results in a wide range of moisture content after drying. Either segregation of stock or special drying procedures may be needed to alleviate this problem. The problem emphasizes need for additional kiln studies and for training in kiln operation.

TIMBER PROCESSING

Uncertainties of the present market have drastically affected the plywood and particle board companies in this territory. Two plywood companies and the single particle board plant stopped operation in the fall even though the particle board company had announced plans for a new plant plus additions to the old one. These companies all expect to resume operations as soon as market conditions become favorable.

Two operators in the region have evidenced interest in production of paper-overlaid lumber. Information supplied by the Forest Products Laboratory has been the basis of their studies to date; but additional promotion and publicity are needed before full-scale production can be started.

One major problem is utilization of narrow and short boards obtained from lodgepole pine. Several companies have started edge- and end-gluing operations aimed at producing wide, clear boards of the higher grades. As other companies install gluing equipment and attain adequate gluing experience, the region should benefit from increased utilization and from manufacture of an increased variety of products.

WOOD CHEMISTRY

Establishment of a charcoal industry within the region is well within the realm of possibility. Thus far, interest in this project has been intermittent, but it has been spurred lately by the popularity of home barbecuing. Latest and best sustained interest has been shown by the Rural Development Committee for Lincoln County, Nevada. This group is investigating possibilities of producing charcoal from pinyon and juniper. Both these trees are characteristically so small sized that considerable research will be necessary before any commercial operation can be started.

RANGE MANAGEMENT RESEARCH

Highlights of range-research problems in the southern part of the station territory were described in the 1952 Annual Report. Last year's report presented an outline of range-research problems in Montana. This year an outline of range-research problems is presented for the Inland Empire Research Center territory in northern Idaho and northeastern Washington. Space permits giving only the highlights, a few basic facts, and a summary of the conclusions.

RANGE PROBLEMS AND RESEARCH NEEDS IN THE INLAND EMPIRE

The area served by the Inland Empire Research Center contains nearly a half million people and 20.45 million acres. Two-thirds of the people and 7.88 million acres are in northeastern Washington; one-third of the people and 12.57 million acres are in northern Idaho.

Almost 50 percent of the land within the Inland Empire is privately owned, 45 percent is federally owned or managed, and 5 percent is owned by states and counties. In northeastern Washington 72 percent of the land is privately owned, but in northern Idaho only 36 percent: this difference reflects relative suitabilities of the land for agriculture.

Forest covers 70 percent of the total land area, cropland 20 percent, and low-elevation grassland the remaining 10 percent. Forest land occupies half the land area in Washington, but four-fifths of the land area in northern Idaho.

Low-elevation grasslands are dominated by a variety of bunchgrass associations. Most of the grassland has been so badly depleted by overgrazing that little of the original perennial cover remains, and considerable invasion of undesirable exotic plants has taken place. Relatively small forest openings occur as mountain meadows and high-elevation herblands.

Forested lands have been classified into four major climax-vegetation zones, each composed of one or more associations. The driest zone is dominated by ponderosa pine, which forms open stands with an undergrowth of herbs and shrubs. The somewhat moister Douglas-fir zone has a denser cover of trees and an understory vegetation predominantly of shrubs. The cedar-hemlock zone has special importance in northern Idaho, for here western white pine occurs as a major seral tree. A subalpine forest zone is dominated by Engelmann spruce and alpine fir.

Forest land in northeastern Washington is largely within the ponderosa pine and Douglas-fir zones, much of it in seral stages dominated by lodgepole pine and western larch. Northern Idaho has land in all four forest zones, including extensive areas in seral stages of the cedar-hemlock. Approximately one-third of northern Idaho is considered noncommercial in terms of timber production; this land is chiefly valuable for watershed, wildlife, and recreation.

Enormous areas of forest in Idaho and Washington were devastated by fire early in this century. The most extensive fires occurred in 1910 when almost one-fifth of the total forest area in northern Idaho was burned. Other large fires occurred in 1919, 1926, 1929, 1931, and 1934. Many of these burned areas have not yet reverted to forest but persist as extensive brush fields. Nearly one million acres of commercial forest land in northern Idaho remain deforested, it has been estimated, primarily because of double burns.

Roughly 7.2 million acres, or 35 percent of the Inland Empire, is grazed by domestic livestock. The significance of forested land to the livestock industry is indicated by the fact that 73 percent of the total area grazed is forest range. Thirty-seven percent of the 14.6 million acres of all forested land receives grazing use by domestic livestock. Forest lands are also the principal habitat for large herds of deer and elk.

Livestock numbers have varied considerably during the past 30 years. In 1925 the area supported almost 200,000 sheep and 187,000 cattle. Sheep have decreased greatly since 1935 and cattle have increased: in 1954 there were almost 70,000 sheep and 373,000 cattle. Estimated value of all livestock in the Inland Empire in 1954 was 38½ million dollars, of which cattle accounted for 95 percent.

Any accurate estimate of the value of the big-game resource is impossible. A computation can be made of expenditures by hunters--it is estimated that between 6 and 10 million dollars are spent annually in the Inland Empire area by hunters seeking deer and elk--but no dollar figure can be applied to the many intangible values of wildlife. One economist estimated that in the entire state of Washington big-game values were equal to 27 percent of all cattle values and 8 percent of all livestock and products. The proportions are undoubtedly much greater in the northeastern part of the State. Because of the large elk and deer herds in northern Idaho, and lesser agricultural activity, the comparative value of big game there is probably much greater than in Washington.

From 1952 to 1955 the annual big-game harvest in the Inland Empire was between 18,000 and 28,000 deer and (practically entirely in northern Idaho) between 5,000 and 9,000 elk. Because of inaccessibility to hunters, it is doubtful whether the elk harvest is equal to the herd potential. Elk are not readily taken in remote areas that can be reached only by pack-string or airplane.

The extensive forest fires mentioned above created vast brush fields and the bounteous big-game habitat responsible for a general buildup of deer and elk during the 1930's and early 1940's. As these brush fields revert to conifers or the shrubs attain heights beyond the reach of animals, progressively less usable range is available. This, combined with reduced fire occurrence and overuse of critical key winter areas, has gradually resulted in a general leveling and even decreases in animal numbers. During severe winters deer and elk are forced to concentrate on very restricted areas along river bottoms and southern exposures at the foot of slopes. These extreme concentration areas are considered critical for maintenance of the big-game herds.

Problems

An outline of broad problems, not necessarily in order of priority, follows:

1. Open low-elevation livestock range (mainly used in fall, winter, and spring)
 - a. Management of nondepleted areas
 - b. Restoration of depleted areas
 - c. Control of undesirable plants
2. Timbered range
 - a. Economic relations of timber and forage
 - b. Management of permanent forest ranges (mostly ponderosa pine zone, used in spring, summer, and fall)
 - c. Management of transitory forest ranges (mostly Douglas-fir and cedar-hemlock zones, used in summer)
3. Mountain meadow summer range
4. Open high-elevation summer range
 - a. Management of fair- to good-condition range
 - b. Restoration of depleted areas
5. Big-game range
 - a. Restoration and maintenance of winter range
 - b. Economic relations of big game and other resources
 - c. Conflict between big game and timber
 - d. Conflict between big game and livestock
 - e. Conflict between big game and watersheds
 - f. Conflict between different kinds of big-game animals

Priority Evaluation

Economically the livestock resource probably has greater importance than big game in the Inland Empire, but the significance of big game, not only as a resource in itself but as an influence on other resources--timber, water, and livestock--is enormous.

Despite the importance of big game to this area, comparatively little has been done to determine suitable methods for management of its habitat. The seral-shrub game habitat in the Inland Empire is unique as a problem type, whereas studies conducted on livestock range throughout the Northwest and northern Rocky Mountain areas can often be applied to livestock range in this area. As a result, the need for research on big-game ranges is believed to be greater than that for livestock ranges in the Inland Empire.

Winter ranges are the limiting factor in controlling big-game numbers in this area; summer ranges appear ample at present. In order to sustain the big-game resource, winter ranges must be maintained in productive condition.

Although the bulk of livestock-grazing land in the Inland Empire is forested, the most critical problems are on high-elevation openings. These are small in area, but when in good condition they are highly productive. Of still greater importance is their sensitivity to irreparable damage from grazing abuse. When their ground cover is disturbed appreciably, the soils erode and both watershed and forage values may deteriorate rapidly. Many areas are eroding at present. The key nature of these areas requires that they be given high priority in research for development of suitable grazing-management and soil-stabilization practices.

Forested range is not so sensitive to damage as the high-elevation openings. However, because of the dominant place of forest ranges in the total grazing resource of the Inland Empire, and because here livestock use must be integrated with timber and wildlife production, the forest ranges should rank high in priority for study. Work on permanent forest range should take precedence over that on transitory forest range, for the former consists of areas that are continually used as grazing lands and must be maintained in satisfactory condition. Transitory ranges are a resource that can be used by livestock for only a few years following timber harvest. The problem of transitory range is largely that of developing a shifting grazing resource compatible with timber production on areas where the primary function is growing trees.

Mountain meadows, despite their small area, are an important source of summer grazing. Most are fairly productive even in poor condition and apparently do not erode until severely depleted. For these reasons research problems of mountain-meadow management are ranked fairly low in priority.

Open, low-elevation livestock ranges are also included in the lower priority classifications. These areas involve less than 25 percent of the total grazing lands. Their only use, aside from minor watershed values, is for livestock grazing. A very great part of this range is depleted, but soil erosion does not appear to be a major problem.

The greatest research deficiency is lack of adequate ecological understanding of the various range types. Achieving full use of the grazing resource and developing sound management practices demand fundamental knowledge of vegetation structure, successional patterns, and how these are affected by grazing. Because this basic information is either sketchy for most areas or lacking entirely, synecological studies and studies of grazing effects are given high priority.

Of major importance also, regardless of range type, is the description and interpretation of indicators of range condition and trend. Such indicators are a vital management tool; their development is directly allied with synecological studies and should receive high study priority.

Project Program

Restrictions in personnel to one permanent man with a summer assistant necessitate careful direction of research effort where it will do the greatest good. Outlined below, in approximate order of priority, are studies for the high-priority problem areas. Only those problems are included that are considered approachable with present resources by 1961.

Big-Game Winter Range

1. Describe the seral shrub complexes that occur in forest-climax zones of the Inland Empire; correlate with stages in succession to the climax-forest type, with different intensities and composition of tree overstory, and with past treatment. Special attention should be given to big-game winter range, but study will apply to livestock transitory forest range as well.

2. Determine the forage value of common shrub species for big-game animals and the effects of degree of utilization. Develop browse utilization standards.

3. Determine the phenology and reproduction methods of primary browse species.

4. Determine methods for returning to available production browse that has grown beyond the reach of game animals.

Open High-Elevation Livestock Range

1. Describe subalpine herblands, their soil and other site characteristics, and classify the plant communities in terms of range-watershed condition.

2. Determine the influence of degree and period of grazing use upon soil stability and forage production.

Livestock Permanent Forest Range

1. Describe the plant communities on the basis of existing classifications, in order to better understand composition and distribution of understory vegetation, primarily in the ponderosa pine zone.

RANGE TREND OVER 25 YEARS ON THE BOISE RIVER WATERSHED

A serious erosion problem has long been recognized on the Boise River watershed. Approximately 7,500 acre feet of silt is estimated to have been deposited in the reservoir during the 12 years following completion of Arrow-rock Dam in 1915. Accelerated erosion probably began shortly after the introduction of large numbers of livestock into the country about 1880 and has been continuing ever since.

The Boise River watershed is characterized by exceedingly steep slopes, narrow ridges, and numerous deep, V-shaped canyons. The soil, which is derived from granite, is coarse, loose, and easily disturbed. The perennial vegetation is chiefly a mixture of bunchgrasses and forbs with Agropyron inerme, Poa secunda, Balsamorhiza sagittata, Astragalus canadensis, and Lupinus spp. prominent at the lower elevations. Shrubs, which dominate certain areas, are mainly Artemisia tridentata, Purshia tridentata, Prunus emarginata, and P. virginiana. The most common annuals are Bromus tectorum and Gayophytum spp.

A system of plots and chart quadrats was established in 1931 in the drainage of the South Fork of the Boise River. The plots were inventoried frequently from 1931 through 1940. In 1940 the project had to be discontinued, and no further observations were made until 1955 and 1956. This report includes salient facts gleaned from study of the plots at the lower elevations (3,900-5,100 ft.) over this 25-year interval.

It is obvious that range improvement, based on several criteria, has taken place generally throughout the watershed. In 1931 about one-third of the plots were dominated by annuals, mainly cheatgrass and Gayophytum; in some areas annuals exceeded perennials on nearly every plot. In 1956 annuals were dominant on only one-tenth of the plots.

Cover of living perennial grasses, forbs, and shrubs, with few exceptions, has increased. In some areas these changes in cover were accomplished by increase in certain species and concurrent decrease in other species. In other plots the species behavior may have been exactly reversed, and this brings into focus the matter of secondary succession following disturbance of the original vegetation by overgrazing.

The pattern of secondary succession appears to be fairly clear-cut on one area, and hints of a similar pattern appear on others. It begins with cheatgrass at the time the plots were established and proceeds from that to Poa secunda and then to a mixture of Agropyron inerme and Koeleria cristata. Broad-leaved forbs such as Balsamorhiza sagittata, Astragalus canadensis, and Lupinus spp. are important components of the vegetation, and abundant evidence indicates that they probably modify the microenvironment favorably toward establishment and spread of perennial grasses. Evidence also indicates that decreases in perennial grasses may be associated with concurrent increases in perennial forbs or shrubs.

On some plots, most of the total change recorded over the span of 25 years occurred during the first 10 years of record; on others most of the change came sometime after 1940, but we cannot tell exactly when because we have no record between 1940 and 1955. On still others the change was apparently continuous over the entire period. These differences, both in species behavior and in the time element, are very likely related to differences in sites and in stages of secondary succession at the time the plots were set out.

In general, the plots in worst condition today, including those that have shown the least improvement (or none at all) are those having southerly aspect. On a few plots that failed to improve, even though they presumably started out in 1931 in the same stage of succession and with the same opportunities as others that did improve, there is indication that trampling disturbance by cattle may have caused the failure. There is also some indication that soil sloughing, which is prevalent on this watershed, is responsible for the erratic behavior of some species, particularly Agropyron inerme. A plant becomes established; then the soil sloughs away; the roots are exposed and the plant dies; another plant comes in and the process is repeated, so the slope is never really stabilized and the amount of cover merely fluctuates.

The quadrat charts show that many individual plants of the common perennial grasses, forbs, and shrubs are at least 25 years old. Some are much older because they were large plants when first charted in 1931. The fact that these old-timers have persisted throughout the period of record and longer on the loose soils that slough so easily lends support to the belief that portions of this country are improving--or at least holding their own against the impact of raindrops, grazing animals, and rodents.

CHEATGRASS ECOLOGY

Phenological observations were made in a 2-acre, stock-proof enclosure in the cheatgrass type south of Boise, Idaho, during the spring and summer of 1957. Measurements of plant height of cheatgrass and two associated perennials, Poa secunda and Sitanion hystrix, were recorded throughout the active growing period. Table 7 summarizes differences in growth rate for these three species. Poa and Sitanion were taller than cheatgrass at all growth stages.

Table 7.--Plant height, in millimeters, of three grasses in the cheatgrass type, and percentage of soil-moisture in the surface 6 inches, in the spring of 1957 near Boise, Idaho

Date	Height			Soil moisture	
	Cheatgrass	Poa	Sitanion	Cheatgrass	Annual forbs
	<u>mm.</u>	<u>mm.</u>	<u>mm.</u>	<u>Percent</u>	<u>Percent</u>
4/10	38	78	216	28	--
4/18	50	81	247	25	17
4/29	76	--	277	19	12
5/6	123	245	296	17	14
5/17	223	283	315	21	11
6/14	--	--	--	9	7
7/24	--	--	--	4	4

The earliest forbs to flower were Lithophragma bulbifera, Lepidium perfoliatum, and Draba verna (April 9). Poa was in full head on April 18, 10 days earlier than cheatgrass and a month earlier than Sitanion. Poa reached

anthesis later than cheatgrass, however, because they both produced flowers at about the same time, between May 6 and May 17. Several forbs also flowered at this time: Sisymbrium altissimum, Amsinckia retrorsa, Zigadenus sp., and Allium sp.

Soil moisture samples were taken at this site from two areas quite different in their ground cover. One area supported a dense stand of cheatgrass and the other a sparse stand of annual forbs--mostly Gayophytum and Draba--with large bare spaces between plants. The soil was a friable, silty clay loam with a fair amount of organic matter in the top 6 inches.

The consistently lower soil moisture in the top 6 inches on the annual forb area indicates that evaporation is probably much more important than transpiration in moisture loss from this level. The cheatgrass area with its protective cover of litter maintained a higher soil-moisture content throughout the period of observation even though its transpiration potential was much greater. Drying of cheatgrass was associated with the marked decline in soil moisture between mid-May and mid-June, but the annual forbs remained green well into the summer, evidently utilizing soil moisture at greater depths.

SEASON OF GRAZING SPRING-FALL RANGE BY SHEEP

It has been shown over a 25-year period that spring grazing by sheep reduces the proportions of grasses and forbs on southern Idaho sagebrush-grass range.^{9/} Under fall grazing at heavy intensity the herbaceous components of the vegetation were maintained, and it was believed that these tended to increase at the expense of shrubs.

In these grazing treatments two 80-acre range pastures were used. Pasture 1 was grazed heavily in the fall at the average rate of 42.6 sheep days per acre. Pasture 2 was grazed in the spring at the average rate of 19.2 sheep days per acre, and again in the fall at 10.0 sheep days per acre. In 1950 a north-south cross fence was constructed and grazing treatments were reversed in half of each of the two pastures. The eastern halves, labeled 1a and 2a, were grazed in fall and spring, respectively, much as they had been in the past. Pasture 1b, the western counterpart of 1a, was grazed in the spring; 2b, the western counterpart of 2a, was grazed in the fall. The grazing treatments were modified so that each pasture was grazed only in the spring at 40 sheep days per acre, or only in the fall at 60 sheep days per acre.

In 1950 and in 1957 the pastures were not grazed. Permanent plots were inventoried in each of these summers by the weight-estimate method. To facilitate summary comparison, the vegetation is divided into three classes--grasses, forbs, and shrubs--and results are expressed in terms of percent composition (table 8).

^{9/} Mueggler, Walter F. Effects of spring-fall grazing by sheep on vegetation of the Upper Snake River Plains. Jour. Range Managt. 3: 308-315. 1950.

Table 8.--Composition of herbage in spring- and fall-grazed range pastures, 1950 and 1957, in percent of total herbage produced

Pasture	Season grazed	Sheep days per acre	Grasses		Forbs		Shrubs	
			1950	1957	1950	1957	1950	1957
			<u>Percent</u>		<u>Percent</u>		<u>Percent</u>	
1a	Fall	60	31	48	34	20	35	32
2a	Spring	40	34	28	11	6	55	66
2b	Fall	60	30	54	11	8	59	38
1b	Spring	40	26	28	42	16	32	56

In terms of absolute production, about the same weight of shrubs was produced on the two pastures in 1950, but only two-thirds the weight of grasses and one-fifth the weight of forbs on the spring-grazed (2a) as compared with the fall-grazed (1a) pasture. Continuation of the contrasting treatments emphasized the differences that had been observed during the previous 25 years: spring grazing penalized grasses and forbs and benefited shrubs; fall grazing had the opposite effect.

The reversed treatments, 2b and 1b, supply confirming evidence. Under spring grazing in 1b, forbs declined from 42 to 16 percent of the total, while shrubs increased from 32 to 56 percent. Under fall grazing (2b) the proportion of grasses increased but the proportion of shrubs declined. In light of their general decline, the forbs do not appear to have been affected adversely by this treatment.

These results support the conclusion that fall grazing by sheep can be a method of improving sagebrush-grass range. Such management may reduce sagebrush gradually over a period of years without the expense or risks of spraying, burning, or mechanical eradication. Furthermore, to achieve range improvement in this way, current forage production need not be completely sacrificed on areas that are rested in spring.

CRESTED WHEATGRASS UNDER BRUSH AND IN THE OPEN

The invasion of sagebrush (Artemisia tridentata) and rabbitbrush (Chrysothamnus nauseosus) into well-established crested wheatgrass stands (both Agropyron cristatum and A. desertorum) has been recognized as reducing the grazing capacity for livestock. On the other hand, grass growing under mature rabbitbrush, and under sagebrush to some extent, may be more vigorous than elsewhere. Weights of grass underneath both shrubs were obtained from caged plots at Benmore in 1957, along with weights from comparable caged plots in the open.

Prior to caging, April 16, two comparable brush plants of each species were selected in each of 24 experimental pastures. One of the two plants was then removed at random. The other brush plant was removed 3 months later when grass weights were measured on all plots, each 9.6 sq. ft. in area. Grass weights away from brush were obtained from two randomly selected caged plots that had been grazed in prior years.

Under sagebrush grass yields are slightly lower than on the brush-free plots (table 9). Seed stalks are also less numerous. These facts suggest that sagebrush competes rather strongly with crested wheatgrass. On the other hand, since grass yields and numbers of seed stalks are markedly greater under rabbitbrush than in the open, it would appear that rabbitbrush does not compete strongly with the grass. The beneficial effects of induced snow drifting in winter, and of reduced insolation and evaporation during the growing season, evidently outweigh the adverse effects of competition of rabbitbrush to a much greater extent than with sagebrush.

Table 9.--Production of crested wheatgrass in mid-July on
9.6 sq. ft. plots with and without brush^{1/}

	Dry-weight yield	Seed stalks
	<u>Gm.</u>	<u>No.</u>
No brush	96.8	213
Sagebrush		
Removed April 16	84.2	130
Removed July 16	70.5	107
Rabbitbrush		
Removed April 16	161.8	308
Removed July 16	155.3	261

^{1/} To convert grams per plot to pounds per acre, remove the decimal point.

Another measure of competitive (and shading) effect is shown by the differences in production resulting from removal of shrubs early in spring (April 16) and removal at the end of active herbaceous growth (July 16). Numbers of seed stalks are increased about 20 percent by early removal of both brush species. The increase in yield from removing sagebrush early is also nearly 20 percent, but the increase from removing rabbitbrush is less than 5 percent.

HALOGETON ON DESERT-SHRUB RANGE

In 1952 halogeton was found in the bottom of Pine Valley both outside and inside the Desert Experimental Range. Plants were small and occurred sparsely inside the experimental range over approximately 8 acres along the southeastern side of the playa in scattered stands of Kochia vestita, Sarcobatus vermiculatus, Atriplex confertifolia, and Salsola kali tenuifolia. By 1953 the infestation had spread 2 to 3 miles across the playa, and seedlings were found in the vegetation along its border.

In June 1954, four areas in the Eurotia lanata and Atriplex confertifolia types on the experimental range were seeded to halogeton. On each area two 8 x 8 ft. plots were planted. On one plot native vegetation was removed before planting, but on the other, halogeton seed was raked in among the native plants. All plots produced halogeton plants in 1954, but plants were small because of drought; they averaged only 5 to 6 inches in height. Plants per plot varied from 8 to 23. In 1955, also a year of low rainfall, halogeton was found on only three of the four areas. After 4 years scattered halogeton plants are found within a 1/4-mile to 1/2-mile radius, primarily to the leeward and downhill, from the planting sites.

Halogeton is now well distributed over the desert outside the experimental range, with heavy infestations along the east and west boundaries. Inside the experimental range new spots are found each year primarily along roadways, on flood plains, and in one or two dry washes. Scattered halogeton plants on protected or moderately grazed areas are usually associated with rodent diggings or adjacent heavy infestations.

DROUGHT AND WINTERFAT MORTALITY

Low rainfall at the Desert Experimental Range during the past 9 years has resulted in low forage production and heavy mortality of many of the native forage plants on both grazed and ungrazed areas. Outside and inside an enclosure in Pine Valley mortality averages 19.0 and 15.6 percent, respectively (table 10). Mortality on the grazed area may be higher than indicated because trampling tends to destroy the dead plants.

Table 10.--Number, cover, height, and mortality of winterfat plants on heavily grazed and ungrazed areas, Pine Valley enclosure, 1957

	Ungrazed area	Heavily grazed area
Plants per 100 sq. ft. (no.)	45	49
Average size of plant (sq. in.)	18.7	5.1
Plant cover (percent)	5.8	1.7
Plant height (inches)	7.6	5.5
Mortality (percent)	15.6	19.0

Although total plant numbers are about equal, the winterfat plants are smaller and less vigorous on the heavily grazed than on the ungrazed range. In consequence, the stunted plants on the heavily grazed range provide less than one-third the cover of the plants on the ungrazed range.

BIG-GAME WINTER RANGE REVEGETATION

Mouse depredations on planted bitterbrush seed seriously limited the success of early seedlings. With the cooperation of the Denver Wildlife Research Laboratory of the U. S. Fish and Wildlife Service, field tests were begun in southwestern Idaho in 1953 of seed treated with compounds intended either to repel or kill mice.

Tetramine (tetramethylene disulpho tetramine) proved to be a reliable seed protectant, but it was withdrawn from the market. Tests made in 1956 showed endrin, a commercially available insecticide, to be promising. It was tested again in 1957, separately and in combination with the fungicides arasan, copper omadine, and zinc omadine (fig. 4). Endrin alone appears to be somewhat inferior to tetramine as a protectant; this is in agreement with 1956 findings. The addition of any of the fungicides, particularly the omadines, resulted in much better protection from rodents than that provided by endrin alone and as good protection as that provided by tetramine.

Figure 4 shows clearly that seedling emergence is inversely related to rodent disturbance. There were on the average 1.7 seedlings per successful seed spot from untreated seed, but between 3.3 and 4.3 seedlings per spot from the five kinds of seed treatment. Both field and laboratory germination trials show no adverse effect due to treatment; in fact, they suggest that the addition of fungicides tends to raise germination rates.

Gibberellic Acid and Bitterbrush

Gibberellic acid was applied to field-sown bitterbrush in southwestern Idaho to determine whether it would improve growth of seedlings. If top growth can be accelerated, the plants may be better able to withstand browsing pressure; and if root growth can be accelerated, the seedling roots may be able to keep ahead of soil-moisture recession during the dry summer season.

Starting in mid-April, gibberellic acid in concentrations of 0, 10, and 100 p.p.m. was applied to three series of bitterbrush seedlings, a third of each series receiving one application at each concentration, and successive thirds receiving two and three applications at 10-day intervals. Periodic measurements showed that, regardless of the number of applications, there were differences in seedling height due to the concentrations of acid they received. These differences narrowed as the season progressed and had no practical significance by the end of August. Gibberellic acid appeared to have no significant influence on development of roots.

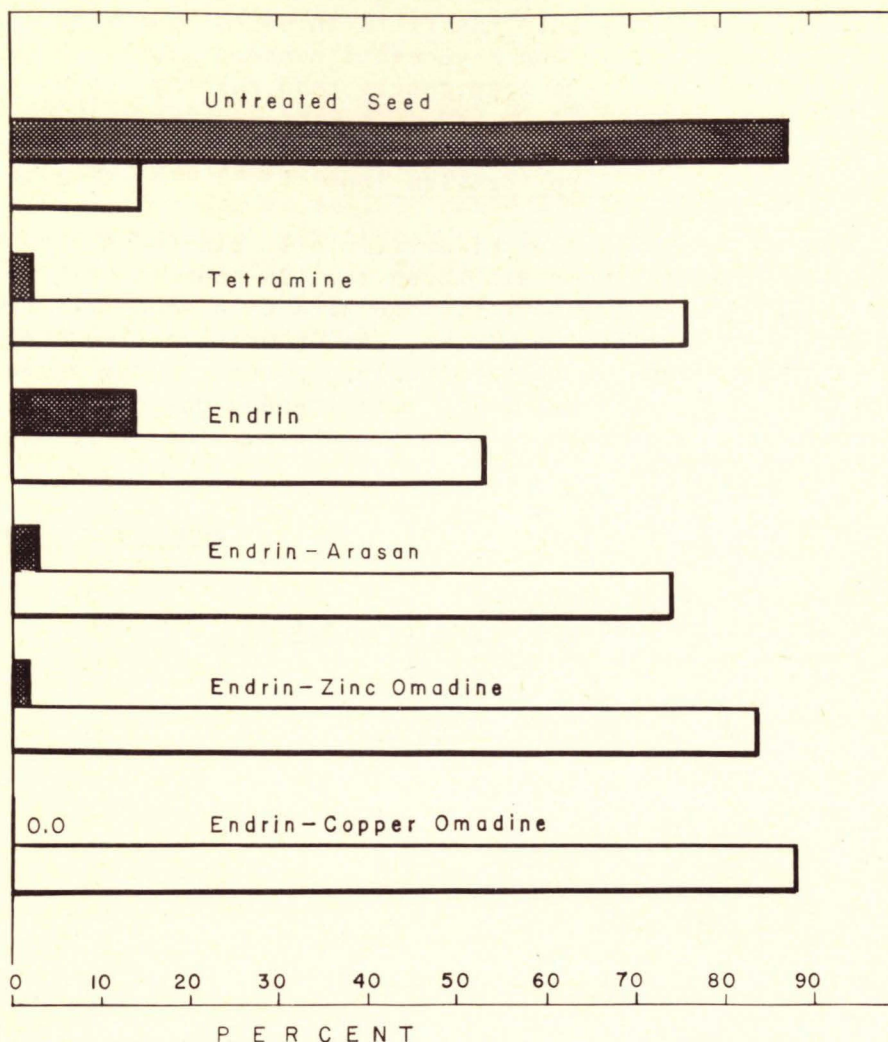


Figure 4.--Percentage of bitterbrush seed spots disturbed by mice (black bars) and percentage of seed spots in which seedlings emerged (white bars) as affected by seed protectants and fungicides.

Seedling Transplants

The transplant technique, whether with nursery stock or with seedlings, is most useful on sites where it is especially difficult to establish plants by direct seeding. Any transplant method is necessarily more expensive than direct seeding, but on some severe sites transplanting may be the only means of getting initial establishment of desirable shrubs. In first trials in central

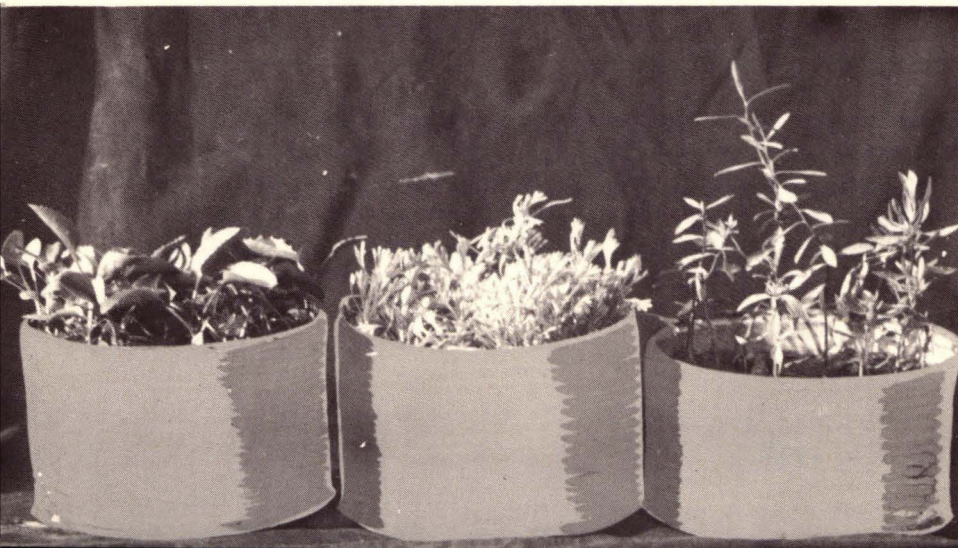
Utah, seedling transplants 6 to 8 weeks old grown in coffee cans (see below), and from these planted directly into the field in holes made with a pulaski, appear to be as successful as 1- and 2-year-old nursery stock. Seedling transplants have the advantage of being less costly than nursery stock, and survival is essentially as good.

Shrub Utilization

Comparative utilization by deer of artificially planted shrubs 8 to 10 years old on two sites in the mountain-brush zone in central Utah is shown in percentages in the following tabulation. One site is a southerly exposure where deer naturally concentrate in winter; the other is a flat where they are less inclined to graze. Snow on the southerly exposure seldom exceeds a few inches in depth, and frequently melts off for extended periods; on the flat the snow may accumulate to a depth of 3 feet. Observations were made during the winter of 1956-57.

	<u>Southerly slope</u>	<u>Flat</u>
Fourwing saltbush (<u>Atriplex canescens</u>)	85	75
Curlleaf mountain-mahogany (<u>Cercocarpus ledifolius</u>)	80	75
Stansbury cliffrose (<u>Cowania stansburiana</u>)	85	80
Antelope bitterbrush (<u>Purshia tridentata</u>)	85	80
True mountain-mahogany (<u>Cercocarpus montanus</u>)	80	40
Winterfat (<u>Eurotia lanata</u>)	80	30
Blueberry elder (<u>Sambucus glauca</u>)	75	10
Big sagebrush (<u>Artemisia tridentata</u>)	50	30
Rubber rabbitbrush (<u>Chrysothamnus nauseosus</u>)	50	30
Gambel oak (<u>Quercus gambelii</u>)	40	15
Dunebroom (<u>Parryella filifolia</u>)	15	T
Mountain snowberry (<u>Symphoricarpos oreophilus</u>)	10	5

Utilization of the four most preferred species--fourwing saltbush, curl-leaf mountain-mahogany, cliffrose, and bitterbrush--was only slightly greater on the southerly site than on the flat, despite the preference of deer for this site. This confirms the observation made on native range that deer seek out highly palatable shrubs regardless of site, if they can get to them.



Seedlings of Palmer penstemon, big sagebrush, and desert almond.

Winterfat, sagebrush, rabbitbrush, and elder were heavily utilized on the southerly slope but only moderately on the flat. Parryella and snowberry were utilized little, even on the concentration area.

These results suggest that deer may be manipulated to some extent by planting shrubs of differing palatability. Palatable shrubs like bitterbrush, curleaff mahogany, and fourwing saltbush can be used to induce deer to flats and north slopes in order to relieve concentration areas. Moderately palatable shrubs like sagebrush and rabbitbrush can be planted on concentration areas: these shrubs provide considerable forage, and their growth habit and ability to reproduce abundantly provide a better ground cover than that provided by more palatable and less aggressive shrubs.

WATERSHED MANAGEMENT RESEARCH

The territory served by the Intermountain station is characterized by extremely varied climate, land forms, and land uses at differing intensities. This diversity poses a severe challenge to research in its task of providing guides and basic information on watershed management. The one reference base is that land management in any form must preserve watershed integrity. Hence the station's program in research on watershed management is concerned with restoration of impaired watersheds, maintenance of watersheds in good condition, and improvement of water yields.

History of land use in much of the nonforested Intermountain area is principally a story of intense grazing accompanied occasionally by rampant fires. These abuses of the plant cover resulted in various degrees of depletion and in many areas resulted in serious land deterioration that will require costly restoration measures.

In the territory of the station's activities the problem of soil stability is critical. Probably in no other section of America is the mountain-valley relationship so characteristic, so vital, and yet sometimes so precarious. Upon this relationship the well-being of much of the Intermountain West depends--water from the mountains for life in the valleys. This relationship appears dramatically in the following photo. Means to alleviate problems affecting this mountain-valley relationship are being sought through the station's research programs.

Within the station territory, annual precipitation ranges from less than 10 inches to about 60 inches. Seasonal distribution is variable, but the greatest portion occurs during the winter months. Important water-yielding areas coincide closely with those having high snowfall. Rapid snow melting, sometimes accompanied by rain, causes high peak flows in the spring that are followed by deficient streamflow when seasonal need for water is greatest. These conditions accentuate the need for water yield improvement measures.

RESTORATION OF DEPLETED WATERSHEDS

Subalpine-Herbaceous Range

Studies of techniques for restoration of subalpine-herbaceous range have had priority at the Great Basin Research Center ever since its establishment in 1912. Studies covering more than 40 years' duration indicate clearly that herbaceous vegetation effectively controls storm runoff and sediment production. However, following severe site depletion and soil erosion, herbaceous vegetation achieves this control very slowly.

The A and B Watersheds afford interesting comparisons of runoff and erosion under various treatments affecting plant cover density. Watershed A has been permitted to revegetate naturally since about 1920, with little or



This Utah town and adjacent farmland illustrate the "mountain-valley" relationship characteristic of this region. Both culinary and irrigation water are derived from high-elevation precipitation, chiefly snow.

no grazing. Ground cover density, after showing an initial improvement the first few years, has changed little during the past 25 years; but changes in cover composition are evident. The watershed continues to produce runoff and sediment: last year sediment production of 5.16 cu. ft. per acre was measured.

Watershed B was subjected to moderate grazing for several years prior to World War II; but after the war it was grazed heavily and became severely depleted. In 1952, intensive treatment was applied to restore the plant cover. This treatment resulted in highly significant improvement in grass cover and a major reduction in broad-leaved forbs. Sediment production (only 0.11 cu. ft. per acre in 1957) is scarcely measurable. Ground cover of plants and litter on Watershed B is now more uniformly distributed than on A, and is comparable to its previous density, which it supported in the late 1940's. Not only have runoff and erosion been greatly reduced, but outstanding improvement in forage quality resulted from the contour trenching and reseedling.

Effects of Plant Cover on Runoff and Erosion

In 1936, 16 plots were installed in the upper portion of the Parrish Watershed (Davis County Experimental Watershed) for measuring surface runoff and soil erosion. Some plots occupied relatively undepleted sites; others were on depleted areas where signs of erosion indicated them to be sources of flood runoff. After 11 years of records were obtained, some of the sparsely covered flood-source plots were seeded to grass; on some others the plant cover was allowed to increase naturally; and some plots were denuded completely. The objectives were to establish a relationship between type of plant cover and overland flow and erosion; to determine the minimum amount of vegetal cover necessary to control runoff and erosion; and to show that depleted flood-source areas can be restored to a nonflood-producing condition.

Plot 7 was one of those denuded completely in 1947. All vegetation and litter were removed or destroyed by cutting, burning, and raking. Records of summer storms, overland flow, and sediment production for the 11-year periods before and after treatment are summarized in table 11.

Table 11.--Number of storms, amounts of overland flow, and sediment eroded from the 0.1-acre Parrish Plot No. 7, 1936-1957

Period	Summer rainfall		Overland flow		Sediment eroded		
	Total storms	Total ppt.	Total storms	Amount	Total storms	Amount	Area
	No.	In.	No.	Cu.ft/A	No.	Cu.ft/A	In.
Before denudation (1936-1946)	130	34.08	23	242.7	0	0	0
After denudation (1947-1957)	161	42.23	49	16,554.9	34	2,426.7	0.67
Total	291	76.31	72	16,797.6	34	2,426.7	0.67

During these 22 summer seasons, 291 storms occurred--72 producing runoff and 34 causing both runoff and erosion. No detectable amounts of sediment were produced by the 23 storms causing runoff prior to denudation. Following treatment, 34 of the 49 runoff-producing storms also caused erosion, and the amount of overland flow increased 33 times that occurring the first 11 years. Erosion occurred at the average rate of nearly 0.02 inch per sediment-producing storm totaling an average loss of 0.67 inch. Erosion has not been uniform over the plot because of rilling; nevertheless it is severe.

The data in table 11 also show that before treatment only about 17 percent of the summer storms caused runoff. After treatment, 30 percent of the storms did.

Correlation analyses show highly significant relationships between the independent variables: total summer rainfall, total individual storm precipitation, and maximum 5-minute rainfall intensity and the dependent variable: overland flow. Sediment production is also significantly related to maximum storm intensity and total storm precipitation.

IMPROVEMENT OF WATER QUALITY

Control of Sediment from Logging Roads

Keeping sediment out of streams on lands being logged is an acute problem. As construction disturbance is extended into unstable, steeper, and less accessible lands, the severity of this problem increases. Encouraging progress was made this year in developing guides for better road location and construction.

Four variables were found to be highly correlated with the distance that sediment flows downslope from newly constructed logging roads. An equation expressing their relationship provides a means of estimating the distance or width of buffer strip required to dissipate sediment movement between roads and streams. A field guide for locating roads so as to keep sediment production at a minimum is being prepared for publication. This approach to a road location and treatment guide provides considerable flexibility in application because several of the equation variables are amenable to control by the road locators.

Logging Disturbance and Sediment Production

Intensified logging operations in areas having unstable soils result in soil disturbance and destruction of plant cover. These result chiefly from ground plowing by skidding logs, churning of the soil by heavy tractors, and construction of numerous haul roads. Erosion and sediment deposition in streams follow inevitably. Yet under a multiple-use management program certain of these areas stocked with mature stands of timber warrant harvesting. How to log these areas and maintain the integrity of the watersheds is being studied on the Boise Basin Experimental Forest.

Watersheds on the 20 logging compartments comprising this study vary in size from 5 to 10 acres up to 35 to 50 acres. Sixteen watersheds have been logged, and the other four have been retained as unlogged controls. Logging operations were controlled stringently; cross ditches were carefully constructed; skidtrails were plugged and ditched wherever necessary; and roads were located with extreme care in consonance with topographic limitations. Sediment basins were constructed in each compartment in 1954 and the stilling ponds were referenced and gridded to establish permanent sediment measuring points.

The areal extent of logging disturbance ranged from 3.6 to 9.1 percent of each compartment. Haul roads constituted 58 percent of the disturbed area, skidtrails 29 percent, and landings 13 percent. Only five of the watersheds (four logged and one unlogged control) are actively producing sediment. Average sediment production per year on the four logged compartments varies from 1.7 to 29.5 tons per square mile; on the control area production is 3.1 tons. The compartment that produces most sediment has a road very near the stream bottom. Reasonable discretion in road location, coupled with adequate safeguards in skidtrail stabilizing treatments, permits logging operations consistent with good watershed management.

Repairing Construction Disturbance

Studies have been undertaken in the loose granitic soils of southwestern Idaho to determine how to reduce soil erosion from logging haul roads and skidtrails to the minimum. Tests of mechanical structures include cross ditches spaced at varying intervals, log bars, and slash plugs in skidtrails on hillsides and ravines. Evaluation of these structures is under way. Answers to such questions as whether skidtrail control structures are properly placed, which type of structure is most efficient, and whether establishment of grass cover aids in erosion control are being sought.

Another study tests different methods of seedbed treatment on the establishment of grass cover on raw surfaces of haul roads. Treatments consist of broadcast seeding, seeding and harrowing, seeding followed by scarification, and scarification followed by seeding. Plots under treatment total 144; of these, 64 received a thin mulch of wood chips.

Observations after one year show that: (1) haul roads can be revegetated by seeding (see photo below); (2) the percentage of plant cover established on northwest aspects exceeds that on southwest aspects; (3) surface mulching



Section of a logging haul road reseeded to stabilize raw soil. A good stand of grass aids in reducing road surface erosion. Raw bank cuts present another problem of stabilization.

with wood chips is of little or no benefit towards plant cover establishment; and (4) scarification scarcely improves establishment of plant cover. This study is being continued to learn the most feasible postlogging treatment for haul roads.

Soil Density-Runoff Relations

Past tests in central and northern Utah and southern Idaho show that for common range conditions 65 percent or more of total ground cover protects effectively against soil loss and reduces materially and sometimes eliminates water loss from surface runoff. Thus, the generalization that runoff varies inversely with the amount of total ground cover is valid.

Further examination of data from a study in central Utah showed that the relationship of runoff to ground cover was also affected by the bulk density of the soil. Throughout the range of ground cover densities, runoff increased uniformly with increased bulk density (figure 5). Under an applied rainfall

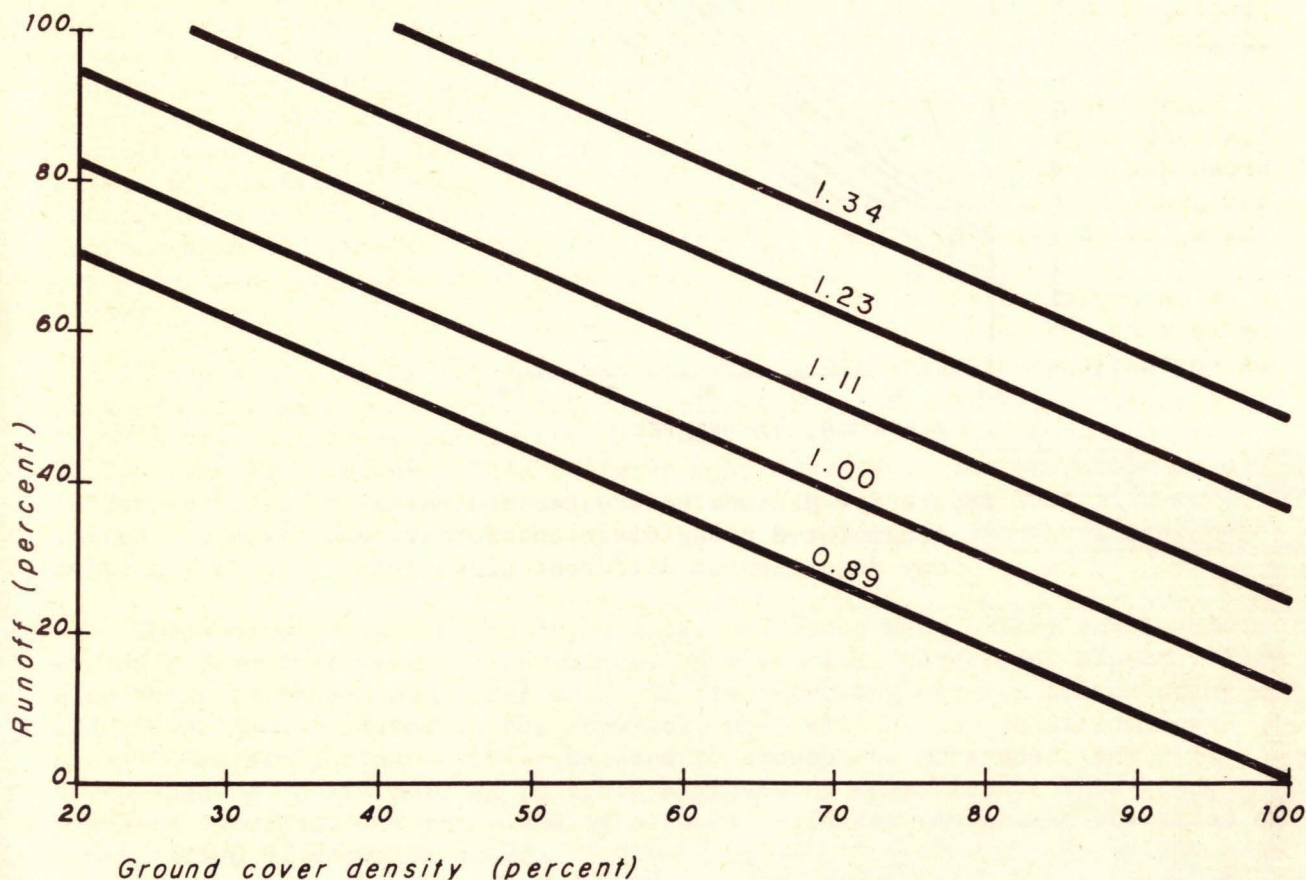


Figure 5.--Runoff from 3 inches of rainfall in relation to ground cover as influenced by bulk density of the surface soil. Numbers on each curve are bulk density values.

of 3 inches, a ground cover of 43 percent sufficed to limit runoff to 50 percent on a porous soil having a bulk density of 0.89. A virtually complete ground cover would be required to obtain the same degree of runoff control on sites having a soil bulk density of 1.34. Excessive trampling by live-stock compacts soil, and the implications of compaction are apparent in the following graph.

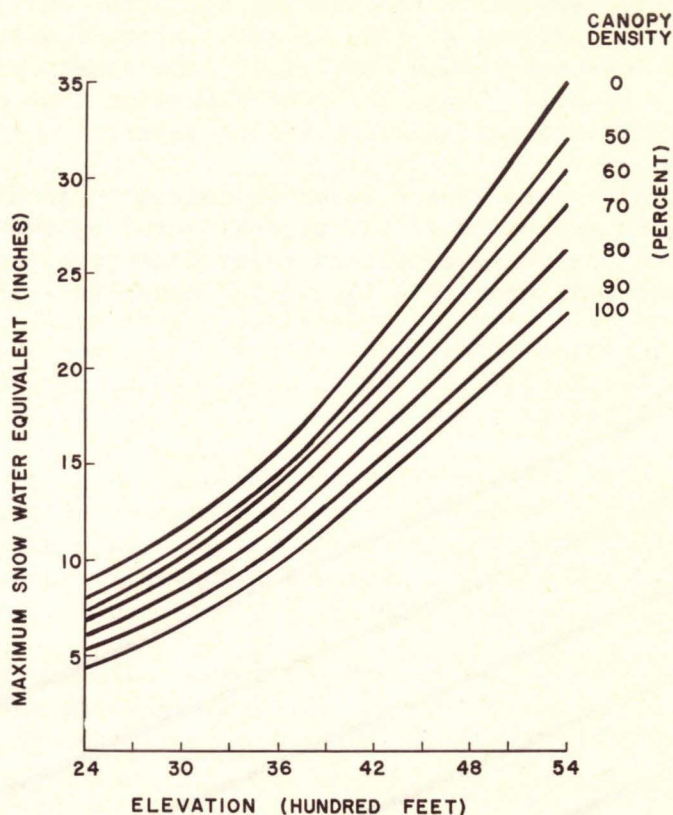


Figure 6.--Maximum snow water equivalent accumulated under different forest canopy densities at different elevations.

IMPROVEMENT OF WATER YIELD

Snow Accumulation in White Pine Forests

Winter snowpack in white pine forests of northern Idaho is a principal source of streamflow for several major tributaries of the Columbia River. Frequently, rapid melting of this snowpack, often accompanied by rain, causes spring flood peaks along these tributaries and aggravates peak discharge stages on the Columbia River itself. Because these forests are subject to harvest, the problem of harvesting them without increasing the flood hazard is posed.

Clues to a solution for this problem were sought in a study of the relationship of snow accumulation to elevation, aspect, and forest cover density. Snow accumulation data were obtained on the Priest River Experimental Forest in northern Idaho during 1949-52 as a part of the Flood Survey division activity. Forty-four snow courses, representing 202 snow-measuring points in the open and 290 points in timbered areas, were measured in those years.

The basic data were stratified by elevational zones, by canopy density classes, and by aspects. Curvilinear regressions developed within separate strata resulted in the series of curves shown in figure 6. Where the canopy density is zero (which corresponds to a clean-cut forest condition) maximum water equivalent exceeds that of increasing canopy densities at all elevations from 2,400 to 5,400 feet. At the maximum elevation of 5,400 feet, the effect of a complete canopy is to intercept almost 12 inches of water. The interception effect of canopy is less at lower elevations, yet the difference between open and timbered areas is significant. Throughout the range of canopy densities, snowpack water equivalent increases with increases in elevation.

Changes from north to south aspects show a significant reduction in snowpack at all elevations. At 5,400-foot elevation, for example, an average of 11.9 inches less water accumulated on south aspects than on north aspects--31.7 versus 43.6 inches. This difference by aspects is due primarily to a longer period of melting on south exposures with consequent loss of water; whereas on north exposures snow accumulation usually continues until spring melting period.

These results are important in watershed management. They enable us to evaluate quantitatively the influences of elevation, cover, and aspect. They also point to other considerations. If clear-cutting permits accumulating an additional foot of water in the snowpack, what will happen to streamflow peaks? Can strip clear-cutting be used to accumulate more snow, and will strip-shading retard melting to avoid aggravating peak flows? This study suggests important and far-reaching effects of forest management practices on manipulation of snowpack water.

Water Yield Improvement Through Snowpack Manipulation

Improvement of water yields in respect to quantity, quality, or timeliness of flow is one major objective of watershed management research. Too often, and unfortunately, the only thought given to water yield improvement is that of producing "more water." This increase, of course, is highly desirable, but not at the expense of increased sedimentation or damaging peak flows of flood magnitude. Research in water yield improvement with respect to both quantity and quality is being accelerated.

Precipitation in 1956-57 in Ephraim Canyon, central Utah, almost equaled the record high precipitation in 1951-52, and exceeded by several inches the 20- to 34-year average. Streamflow of Ephraim Creek in June 1957 was the highest ever recorded--14,092 acre feet. The previous high was 10,635 acre feet in 1942 and the past 16-year average 6,061 acre feet.

To regulate timeliness of streamflow by snowpack manipulation to modify this early season discharge has utmost importance. Early tests showed that fences effectively induce snowdrifting that delays snowmelt for about 2 weeks on high-elevation, herbaceous ranges. Similar effects of induced snowdrifting behind such obstacles as clumps of trees can be observed each year (see following photo.) If peak streamflow, such as was experienced in June, could be reduced and runoff strengthened in later months enormous benefits would accrue. To explore further the possibility of improving timeliness of flow, a new snow manipulation study was begun this year. The study is divided into three phases: (1) tests of fence heights, spacing, and orientation with respect to wind direction and topography; (2) treatment of a small calibrated watershed to determine the efficacy of fence structures; and (3) reforestation of watersheds in strips to achieve drifting by natural vegetation. This study will require several successive seasons. Results will be reported periodically.



Snowdrift formed behind clump of trees on high elevation range, central Utah. The drift extended about 50 feet from the trees. Its maximum depth was 6 feet, and its width 25 feet at base in early June. Note typical mature drift shape.

Progress of Type Conversion Plans

Evapotranspiration losses of aspen stands exceed those of brush and herbaceous types of vegetation on high elevational areas in northern Utah. Interest in vegetation type conversion to improve water yields is mounting. Two projects pointed toward solving this problem are under way: One is a study of summer water use by aspen and mountain brush; the other involves calibration of paired aspen-covered watersheds. Five years' streamflow records reveal a high correlation ($r = 0.994$) between the flows of the two streams. When this relationship is determined to be sufficiently stable to permit prediction of streamflow of one from that of the other, conversion of cover on one watershed will be made and its effects evaluated.

Research Program Starts in Nevada

Steps have been taken toward starting research on watershed problems in western Nevada and parts of eastern California. These include transfer of a watershed management specialist to Reno, reactivation of the Nevada Research Center, and the commencement of a problem analysis for that area.

How to reduce flood discharges and increase timber and forage productivity of the Jeffrey pine and brushlands on the east slopes of the Sierra Nevada appear to be high priority research problems. In recent years, winter floods caused by rapid melting of deep snow and summer floods from torrential rains have increased in frequency and destructiveness. Flood damage in the Reno area alone now averages nearly \$1 million per year. Flood runoff originates, in part, on lands below which major structural control is not feasible. The flood-source areas have been drastically depleted of plant cover by past fires, timber clear-cutting, and overgrazing. Now these lands contribute only a fraction of their potential value to the regional economy and appear to have lost much of their storage capacity essential to flood prevention. Research must develop feasible restoration techniques for rehabilitating these important watersheds.

PUBLICATIONS

A. Departmental publications

LEAPHART, CHARLES D., OTIS L. COPELAND, JR., and DONALD P. GRAHAM.
Pole blight of western white pine. U. S. Dept. Agr. Forest Pest
Leaflet 16. 4 pp., illus.

An up-to-date account of pole blight symptoms, distribution, and damage.
Discusses research to determine the cause of this disease.

WASSER, C. H., LINCOLN ELLISON, and R. E. WAGNER. Soil management on
ranges. U. S. Dept. Agr. Yearbook 1957: 633-642.

Thumbnail sketch of range-management objectives, ecological trends under
grazing, grazing management practices, and methods of artificial range improve-
ment.

WOODS, FRANK W., OTIS L. COPELAND, JR., and CARL E. OSTROM. Soil manage-
ment for forest trees. U. S. Dept. Agr. Yearbook 1957: 710-715.

Describes management practices consisting chiefly of indirect measures.
Discusses problems of water excesses and deficiencies, and offers recommenda-
tions. Reviews forest disease, soil relationships, and fertility require-
ments of trees.

B. Publications in scientific and professional journals, etc.

BARROWS, J. S. Project Skyfire--A progress report on lightning fire
research. 48th Ann. West. Forestry Conf. Proc., West. Forestry and
Conserv. Asso., pp. 54-56.

Summarizes the lightning fire problem in western forests and discusses
the organization of the Project Skyfire research program. Presents prelimi-
nary results of cloud-seeding research during the 1957 fire season.

BARROWS, J. S., JOHN H. DIETERICH, CLYDE A. O'DELL, CHARLES H. KAEHN,
U. S. Forest Service; DONALD M. FUQUAY, VINCENT J. SCHAEFER, and
PAUL B. MacCREADY, JR., The Munitap Foundation, Inc., DeVER COLSON,
U. S. Weather Bureau; H. J. WELLS, Advisory Committee on Weather
Control. Project Skyfire, reprinted from Final Report of Advisory
Committee on Weather Control. U. S. Govt. Printing Off., Washington,
D. C., pp. 105-125.

Discusses preliminary results of all phases of Project Skyfire. Five
tentative conclusions are presented on cloud modification and artificial
nuclei studies.

COPELAND, OTIS L., JR. Ecological considerations of the pole blight disease. Fourth Internatl. West. Disease Work Conf. Proc., pp. 49-55.

Reviews the occurrence of western white pine pole blight and damage caused by this disease. Also reviews research conducted to determine the cause of pole blight. Discusses climatic, edaphic, and biotic factors as possible contributing causes of the disease.

COPELAND, OTIS L., JR. A study of the influence of moisture and compaction on soil oxidation-reduction potentials. Soil Sci. Soc. Amer. Proc. 21(3): 269-271.

Soils receiving the optimum moisture-no compaction treatment maintained the highest state of oxidation during the test, while the saturated high-compaction series developed the lowest potentials. The positive poisoning capacity of the test soils is attributed to large quantities of hydrated iron oxides coupled with a paucity of active organic matter.

DODGE, HAROLD R. Defoliating insects in the northern Rocky Mountains in 1955. Northwest Sci. 31(1): 38-42, illus.

Describes the extent and severity of infestations of several insect pests of coniferous forests.

ELLISON, LINCOLN. Grazing standards in range management. New Zealand Grassland Assoc. Proc. of 18th Conf. Nov. 27-29, 1956: 136-147.

Judgment of range condition and trend rests upon two principles: prevention of accelerated erosion and use of the potential of the specific site as a standard. The evidence of process written on the range in the form of indicators must be our first and final authority; interpretation of these indicators must relate to the particular ecosystem with which we are dealing.

ELLISON, LINCOLN. Applications of ecology--concluding statement (in symposium on applications of ecology). Ecology 38(1): 63-64.

Comments upon preceding papers (on applications of ecology in forest, range, wildlife, and wild land soil management and in public health) in light of their contributions to ecological understanding, and upon the need for free interchange of ideas among subject-matter fields.

ELLISON, LINCOLN. A panel discussion of the place and functions of the division of range management in the Society of American Foresters: historical sketch. Jour. Forestry 55(4): 312-313.

The big problem--that of promoting coordinated wild land management--is still unsolved by existing professional societies. Although the formation of subject-matter divisions in the S.A.F. attempts this coordination, the author doubts whether the range division can contribute effectively to solution of the problem because few range men belong to the S.A.F.

FRISCHKNECHT, NEIL C., and ALVIN T. BLEAK. Encroachment of big sagebrush on seeded range in northeastern Nevada. Jour. Range Mangt. 10(4): 165-170.

Of the sagebrush present 10 years after treatment, about one-fifth was old plants that had survived eradication, three-fifths were plants that had become established at the time of seeding, and one-fifth was plants that had invaded after establishment of the crested wheatgrass--mostly in areas where grazing use had been heavy. Halogeton has recently invaded heavily grazed and barren spots.

FUQUAY, DONALD M., The Munitalp Foundation, Inc., and KONRAD BUETTNER, University of Washington. Laboratory investigation of some characteristics of the Eppley pyrliometer. Amer. Geophys. Union Trans. 38(1): 38.

Laboratory investigations have confirmed field observations of inconsistent behavior of the Eppley pyranometer. Describes experiments and theories to explain ways to avoid the following errors: (1) Variable temperature coefficient; (2) variation of thermopile output with direction of gravity, and effect caused by internal air convection; (3) errors caused by radiation coming from the back side and being reflected by the glass cover; (4) errors from specular reflectivity of the black receiver ring and the resulting deviation of response from the cosine law.

GIBSON, ARCHIE L. Tests of bark penetrating insecticides to control the Douglas-fir beetle. Jour. Econ. Ent. 50(3): 266-268.

Reports the amount of Douglas-fir beetle brood mortality achieved by the application of several insecticides to bole sections of infested trees; describes formulations employed and the mode of application.

JOHNSON, PHILIP C. Report on insect enemies in (the northern) Rocky (Mountain) region. West. Conserv. Jour. 14(1).

Describes current insect infestations in the forests of the northern Rocky Mountains.

LEAPHART, CHARLES D., and OTIS L. COPELAND, JR. Root and soil relationships associated with the pole blight disease of western white pine. Soil Sci. Soc. Amer. Proc. 21(5): 551-554.

Shows the relationship between the rootlet condition of white pine pole stands affected by pole blight and two soil characteristics, effective soil depth and available moisture-holding capacity. Reviews factors affecting various root characteristics in healthy white pine stands ranging from 20 to 110 years old.

LYNCH, DONALD W. Simplified method of teaching use of compass. Fire Control Notes 18(2): 62-63.

Describes and illustrates a method of teaching use of the Forest Service compass, especially to groups of students at guard schools. This method employs a wooden model with the stationary "compass needle" oriented toward magnetic north and the body of the compass free to rotate beneath it.

MacCREADY, PAUL E., JR. The Munitalp Foundation, Inc. The Munitalp cloud theodolite. Amer. Met. Soc. Bul. 38(8): 460-464.

Describes various forms of the instrument and gives the method of determining cloud direction and velocity with the cloud theodolite. Discusses instrument errors.

NAGEL, R. H., DAVID McCOMB, and F. B. KNIGHT. The trap tree method for controlling the Engelmann spruce beetle in Colorado. Jour. Forestry, 55(12): 894-898.

The natural preference of the beetle for breeding in freshly felled green trees has been used in field tests to develop a practical method of limiting or preventing attacks of the beetle in living trees. Freshly cut green trees deployed in strategic locations throughout the forest concentrate and absorb the resident beetle populations where they may be subsequently destroyed. Describes techniques and compares the beetle population densities in the felled "trap" trees and nearby living trees.

PLUMMER, A. PERRY, ROBERT L. JENSEN, and HOMER STAPLEY. Range revegetation. Utah Fish and Game Magazine 13(6): 8-9.

A progress report on the first 2 years' results of artificial shrub revegetation in central Utah: some promising species.

ROTH, ELMER R., and OTIS L. COPELAND, JR. Uptake of nitrogen and calcium by fertilized shortleaf pine. Jour. Forestry 55(4): 281-284.

Littleleaf-diseased trees that received nitrogen made pronounced recovery and contained normal amounts of nitrogen one year after treatment. Growth increases accompanied improvement of crown appearance. No improvement in disease symptoms resulted from applied calcium.

SCHAEFER, VINCENT J. The Munitalp Foundation, Inc. Atmospheric studies from a moving weather observatory. Amer. Met. Soc. Bul. 38(3): 124-129.

The moving weather observatory is described, and techniques for its operation are explained. The results of a mountain wind and temperature study are used to determine its value as a piece of mobile weather equipment.

SCHAEFER, VINCENT J. The Munitalp Foundation, Inc. The relationship of jet streams to forest wildfires. Jour. Forestry 55(6): 419.

Reports on the relationship between dry, gusty ground winds and the proximity of the high level jet stream. A case example is described where a forest wildfire was thought to be directly caused by a pivoting jet stream.

SQUILLACE, A. E. Variations in cone properties, seed yield, and seed weight in western white pine when pollination is controlled. Mont. State Univ., School of Forestry Bul. 5, 16 pp., illus.

Seeds borne on shoots in the upper and outer crown and on the south and west sides of individual trees tended to be heavier than those in opposing portions of the crown. Cones borne on the more fruitful shoots tended to be longer and contained heavier seeds than those on the less fruitful shoots. Average weight of seeds in individual cones was found to be directly related to cone length and scale size and inversely related to seed yield. Longer cones usually yielded more seed but yield was also affected by pollen parent. An apparent effect of pollen parent upon the shape of cone scales was also found.

STAGE, A. R. Some runoff characteristics of a small forested watershed in northern Idaho. Northwest Sci. 31(1): 14-27.

Sixteen years' records on Benton Creek show that two-thirds of each year's runoff occurred during April, May, and June. Average annual runoff from the Benton Creek Watershed is estimated to have been 11.2 inches for the period 1911-55. Evapotranspiration losses are estimated to have been 25.0 inches for the same period.

TACKLE, DAVID. Protection of ponderosa pine cones from cutting by the red squirrel. Jour. Forestry 55(6): 446-447.

Banding isolated ponderosa pine seed trees with a sheet of 18-inch-wide, smooth aluminum prevented red squirrels from climbing the trees and cutting cones and cone-bearing branches. Narrower bands were ineffective. Protected trees (trees with 20-inch bands) with branches 5.3 feet or more distant from the branches of adjacent unprotected (unbanded) trees did not experience cone or branch cutting by squirrels. Under normal conditions a 7- or 8-foot isolation should prevent jumping by squirrels from unbanded to banded trees, since under escape conditions, red squirrels have been observed to jump 7 feet horizontally and to span 10 feet in a downward diagonal drop.

U. S. DEPT. OF AGRICULTURE. Project Skyfire. Picture story 104, USDA, Office of Information, Washington, D. C.

Briefly describes the operational phases of the project and its attack on the basic lightning storm problem.

C. Processed reports

BASILE, JOSEPH V., and RALPH C. HOLMGREN. Artificial revegetation studies on depleted big-game winter ranges in Idaho. Job Completion Reports, Project W-111-R-3. Idaho Fish and Game Dept., 11 pp.

A comparison of five chemical formulations as protectants of sown bitterbrush seed against rodent depredation. Effects of deer on browse revegetation, and results of species adaptability tests are also given.

BASILE, JOSEPH V., and RALPH C. HOLMGREN. Seeding-depth trials with bitterbrush (Purshia tridentata) in Idaho. Research Paper 54, 10 pp., illus.

Describes tests over a 6-year period, under conditions suitable for machine and hand seeding of bitterbrush, to show relation of seeding depth and seed-group size to time and rate of seedling emergence, frost heaving, and survival.

BINGHAM, R. T., and A. E. SQUILLACE. Phenology and other features of the flowering of pines, with special reference to Pinus monticola Dougl. Research Paper 53, 26 pp., illus.

In western white pine the average date of first anthesis at high elevation was July 8, at low elevation June 27. Average period of pollen dissemination was $8\frac{1}{2}$ days, ovulate flower receptivity $9\frac{1}{2}$ days. Flowering was delayed approximately 5 days per 1,000 feet increase in elevation, and 6 days per degree F. departure of May and June temperature below normal. Individual trees were found to be consistently early or late in time of onset of flowering, and the sequence of flowering between localities was firmly fixed.

COLSON, DeVER. U. S. Weather Bureau. Thunderstorm analysis in the Northern Rocky Mountains. Research Paper 49, 13 pp., illus.

Describes methods used to survey cloud and thunderstorm conditions. Reviews three types of thunderstorms occurring in the northern Rocky Mountains, and presents data on several thunderstorm situations.

CURTIS, JAMES D., and DONALD W. LYNCH. Silvics of ponderosa pine. Misc. Pub. 12, 38 pp., illus.

A description of the silvics of the species based on available data through 1956. Includes dendrological features and mensurational characteristics considered pertinent to development and growth, from flowering stage and germination of seed to the overmature tree.

DIVISION OF FOREST INSECT RESEARCH. Forest insect conditions in the Intermountain and northern Rocky Mountain States during 1956. Misc. Pub. 11, 6 pp.

Presents the results of cooperative forest insect surveys for 1956. Statements on the more important insects are included.

DODGE, HAROLD R., TOM T. TERRELL, and PHILIP C. JOHNSON. Entomological phases of the 1955 Montana spruce budworm control project. Misc. Pub. 9, 20 pp., illus. (Note: this reference did not appear in the 1956 annual report.)

Describes biological techniques and observations needed to assure successful control of the budworm on 372,652 acres of Douglas-fir forests in Montana during July 1955. Special reference is made to the progress of larval development needed to time the application of DDT aerial insecticide, to the insecticide formulation and its mode of application, to the physics of aircraft spraying, and to the method of determining the lethal effectiveness of the insecticide application.

FRISCHKNECHT, NEIL C. Effects of various grazing treatments on crested wheatgrass. Wash. State Col. Dept. Anim. Husb. Stockmen's Handb. 1956: 28.

Removal of 80 percent of the current year's growth of crested wheatgrass for eight consecutive years resulted in deterioration of the grass and increase of brush and other undesirable species. Sixty percent annual removal was considered more nearly proper to achieve maximum sustained forage and animal production.

FRISCHKNECHT, NEIL C. Managing crested wheatgrass for greatest cattle gains. Wash. State Col. Dept. Anim. Husb. Stockmen's Handb. 1956: 29-30.

Cattle gains under 12 grazing treatments are discussed. Intensity of grazing influenced daily animal gains and gain per acre more than system of grazing did.

FUQUAY, DONALD M., and H. J. WELLS. The Project Skyfire cloud-seeding generator. Research Paper 48, 17 pp., illus.

Describes two basic generator types and gives the reasons for developing a new generator. Summarizes calibration procedures and results.

FURNISS, MALCOLM M. Entomological aspects of the 1955 southern Idaho spruce budworm control project. Misc. Pub. 10, 29 pp., illus.

Describes procedures for gathering biological data necessary for determining spraying dates, checking spray deposit, and assessing mortality. Some problems attending spray operations are discussed and recommendations made for improvement in methods.

HUTCHISON, S. BLAIR. Market prospects for Mountain States timber. Research Paper 50, 31 pp., illus.

Analyzes the long-range prospects for increased utilization of the timber resources in the eight Mountain States. Attempts to interpret the national timber outlook described in the Forest Service's TIMBER RESOURCE REVIEW in terms of what it may offer as industrial opportunities for the Mountain States.

HUTCHISON, S. BLAIR, and JOHN H. WIKSTROM. Industrial opportunities in the headwater timber development unit. Research Paper 45, 70 pp., illus.

The Headwaters Timber Development Unit is a 5-million-acre area of commercial forest in southeastern Idaho, western Wyoming, and the northern edge of Utah. At present, relatively little use is being made of this timber. The report indicates the extent of industrial development possible from this resource and attempts to describe the type of development that would make fullest use of it.

KEMP, PAUL D. Regression coefficients for computing cubic-foot volume of Rocky Mountain trees. Research Paper 40, 12 pp.

Presents the regression coefficients used to adapt Forest Survey cubic-foot volume tables to the computation of volume by formula on IBM punch card machines. The regression coefficients vary by species and one-tenth d.b.h. classes.

KEMP, PAUL D. A procedure for converting conventional tree volume tables (cubic) to formulae (Part 1). Research Paper 43, 7 pp., illus.

Presents the basic procedures used to develop the regression coefficients presented in Research Paper 40.

LYNCH, DONALD W. How many trees should be log graded to determine sales realization value. Research Note 45, 6 pp.

An accurate sales realization value (sales price of manufactured lumber) for log graded timber sales can be determined by sample grading a portion of the trees. Standards for obtaining the sample for prescribed levels of accuracy and probability are presented in tables and equations.

LYNCH, DONALD W. Truck load sample scaling to adjust company scale. Research Note 48, 7 pp.

Describes a system of sample scaling that determines an adjustment factor to bring company scales (which are customarily 100 percent gross scales) to Forest Service net standards. Points out that an adjustment factor (to any desired degree of accuracy) can be determined with less scaling than is required to achieve an equally accurate average volume figure in conventional sample load scaling.

MIELKE, JAMES L. Aspen leaf blight in the Intermountain region. Research Note 42, 5 pp.

Contains information on distribution and hosts of the fungus, epidemiology, symptoms of the disease, and character of damage to aspen.

MIELKE, JAMES L. The Comandra blister rust in lodgepole pine. Research Note 46, 8 pp.

This rust fungus is now epidemic in many stands of lodgepole pine in the Intermountain region. Its distribution, hosts, life history, character of attack and damage to the pine, epidemiology, ecology of the alternate host, relation of rodents to the fungus on pines, and control are briefly discussed.

MIELKE, JAMES L. The yellow witches' broom of subalpine fir in the Intermountain region. Research Note 47, 5 pp.

Yellow witches' broom disease is epidemic on several areas in the Intermountain region. The range of the rust, its hosts, life history, description of the disease on subalpine fir, damage, epidemiology, ecology of the alternate hosts, and control are briefly discussed.

MOESSNER, KARL E. Preliminary aerial volume tables for conifer stands in the Rocky Mountains. Research Paper 41, 17 pp., illus.

Presents preliminary board-foot and cubic-foot aerial volume tables prepared from 168 randomly selected Survey field plots, together with some tests of these tables on individual field plots not used in the table. Discusses use of the tables in plot measurement.

MOESSNER, KARL E. How important is relief in area estimates from dot sampling on aerial photos? Research Paper 42, 16 pp., illus.

Presents results of a study of the theoretical bias introduced by sampling directly on aerial photos in mountainous areas. Data indicate that proportions obtained from samples located by photo center did not differ significantly from those obtained when samples were located by map.

MOESSNER, KARL E. Relation of minimum area standards to proportions obtained by dot samples on aerial photos. Research Paper 44, 13 pp., illus.

Presents results of a study comparing proportions obtained by sample plots varying in size from one-fifth acre to 40 acres. Indicates a significant overestimate of forest land was obtained when large sample plots were used in predominantly forest areas having many small mountain meadows. When the strata sampled occurred both in large and small size tracts, the proportions obtained did not differ significantly by plot size. Also indicates use of large plots significantly increases the cost of sampling on aerial photos.

MOESSNER, KARL E., and EARL J. ROGERS. Parallax wedge procedures in forest surveys. Misc. Pub. 15, 24 pp., illus.

Describes and demonstrates use of the parallax wedge in making measurements from aerial photos. Indicates applications to a variety of problems in forest survey.

ORR, HOWARD K. Effects of plowing and seeding on some forage production and hydrologic characteristics of a subalpine range in central Utah. Research Paper 47, 23 pp., illus.

Reseeding and protection from grazing for 3 years achieved substantial improvement in quality and quantity of subalpine-herbaceous forage on parts of the Manti Canyon range rehabilitation project area. Further improvement, particularly in storm runoff and erosion control, is expected within the next few years.

PACKER, PAUL E. Intermountain Infiltrimeter. Misc. Pub. 14, 41 pp., illus.

An illustrated manual describing an infiltrimeter apparatus developed by the author and used in several studies in Utah and Idaho. Includes specifications for construction and gives directions for operation.

PLUMMER, A. PERRY, ROBERT L. JENSEN, and HOMER D. STAPLEY. Job completion report for game forage revegetation project W-82-R-2. Dept. Inf. Bul. 31, Utah State Dept. of Fish and Game, 128 + vi pp.

Information on forage production, rate of survival, adaptability of species tested to various sites, and preliminary results of superior strains of browse species for artificial revegetation is reported.

STAGE, A. R. Speedy scaling of low-value log-loads. Research Note 50, 4 pp., illus.

Measurements of load circumference, length, and number of logs were related to load volume as a way of scaling long-log pulpwood at a cost and accuracy commensurate with the value of the product.

WIKSTROM, JOHN H. Lodgepole pine--a lumber species. Research Paper 46, 17 pp., illus.

Lodgepole pine, a soft-textured softwood, has the properties to make good lumber. Production of lumber from this species is increasing. Because lodgepole pine trees are small, they produce a high proportion of narrow boards; difficulty of marketing these narrow boards imposes a handicap on the species.

WILSON, ALVIN K. A new high in Montana Christmas tree shipments. Research Note 44, 4 pp.

Montana Christmas tree shippers set an all-time record in 1956 by exporting nearly 4.2 million trees to markets in other states. Substantial increases over 1955 shipments occurred in all the principal tree-shipping counties. Eighty percent of the total shipments were by rail.

WILSON, ALVIN K. Northern Rocky Mountain pole production continues climb in 1956. Research Note 49, 4 pp.

The Montana-north Idaho-northeast Washington area produced 577,650 poles in 1956, an increase of 96 percent over 1955 production. Lodgepole pine, with 41 percent of the total, was the leading species, followed in order by western redcedar, western larch, and Douglas-fir. 1956 production was the third highest for any year since 1947. Western redcedar was displaced as the leading species for the first time since 1947.

WILSON, ALVIN K., and GORDON H. GREENWAY. Costs of logging virgin ponderosa pine in central Idaho. Research Paper 51, 15 pp., illus.

Data collected from a timber sale on the Boise Basin Experimental Forest relate logging costs to several variables including two logging methods, two marking methods, and two levels of reserve stand volume in the virgin ponderosa pine type of central Idaho. Tables show the distribution of logging costs for a reasonably typical operation in terms of man- and equipment-hours per M board feet and as percentages of the total cost of logs delivered to the mill.